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## ORIGINAL PAPERS

### THE ELECTROLYSIS OF SODA-LIME GLASS—PART II[1,2]

BY J. W. REBBECK, M. J. MULLIGAN AND J. B. FERGUSON

ABSTRACT

The electrical resistance of soda-lime glass is markedly increased by suitable heat treatments. An investigation has been carried out upon the effect of the time of annealing on the resistance and the temperature coefficients of the resistances of annealed and unannealed glass. Migration experiments indicate that the major factor in the increasing of the resistance by annealing is probably a decrease in the speed of the carriers. The apparent resistance of glass is also a function of the extent to which the glass has been electrolyzed. In unaltered glass the conduction is in accord with Ohm's Law but with glass that has been electrolyzed under certain conditions the apparent resistance is a function of the applied voltage.

#### Studies in Electrical Resistance

Tool and Eichlin[3] have recently shown that both the density and the thermal behavior of glass may be altered by proper heat treatments and intimate that perhaps other properties may also be affected by such treatments. In line with these deductions are the observations of many other investigators. Foussereau[4] was perhaps the first to note the marked

[1] Contribution from the Chemistry Department, University of Toronto.

[2] Part I—"Evolution of Gas and Its Relation to Sorption and Conductivity," J. W. Rebbeck and J. B. Ferguson, *Jour. Amer. Chem. Soc.*, **46**, 1991 (1924).

[3] Tool and Eichlin, *Jour. Amer. Ceram. Soc.*, **8**, 1 (1925); *Jour. Op. Soc. Am.*, **8**, 419 (1924).

[4] Foussereau, *Compt. rend.*, **96**, 785 (1883).

effect of annealing upon the electrical resistance and was followed by Gray and Dobbie[1] who carried out a partial investigation of this phenomenon in 1900. The present paper deals with certain aspects of this problem and with an allied problem—the changes in the electrical resistance induced by electrical treatments.

## General Procedure

The measurements were made with glass tubes similar to those described in Part I. The tubes were constructed from tubing 11 mm. bore and 0.7 mm. wall thickness, and tubing 4 mm. bore and 0.7 mm. wall thickness. The thicker part of each tube was 6–8 cm. long and the other part was of sufficient length to eliminate errors from electrical leakage. The soda-lime glass was similar to that used in Part I.[2] The tubes were partly filled with mercury by distillation in a good vacuum. The resistances were determined by measuring with a potentiometer the fall of potential across a standard resistance which was in series with the sample tube. The form of the sample tube and the scheme of the electrical connections are given in Fig. 1. The outer electrode, in all the experiments conducted below 100°C, was an aqueous solution of sodium hydroxide of approximately 5% by weight. At higher temperatures either glycerine or molten silver nitrate was used. Constant temperatures were obtained by means of controlled water or air baths. Electrical leakage was observed by withdrawing the wire connecting the inner electrode to a position just above the surface of the mercury and taking a reading with the potentiometer.

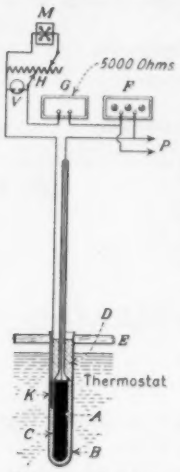


FIG. 1.—Apparatus for resistance measurements.

## Ohm's Law

When the time of measurement did not exceed a few seconds, the resistance measurements with unaltered glass[3] were independent of the direction of the current. Both at 75°C and 94°C we were unable to detect deviations from Ohm's Law with unaltered glass greater than our experimental errors (one per cent or less) though we used potential gradients ranging from 322 to 1610 volts per cm. A few results at 46 and 60°C indicated a similar behavior at these lower temperatures. The experiments

[1] Gray and Dobbie, *Proc. Roy. Soc.* (*London*), **67**, 200 (1900).

[2] $SiO_2$ 71.08%, $Na_2O$ 18.85%, CaO 6.22%, MgO 3.38%, with small amounts of $Al_2O_3$, $Fe_2O_3$, ZnO.

[3] By unaltered glass we mean glass, the composition of which has not been changed by electrolysis.

were carried out with both ordinary and annealed glasses[1] and agree with those made at higher temperatures by a number of investigators,[2] who found that this law held for similar glasses in the temperature interval 191–350°C. The fact that Ohm's law is obeyed at the lower temperatures noted by us would seem to render probable the assumption that the law also holds at room temperature for the kinds of glass and the range of potential gradients used by us at the higher temperatures.

## Annealing

The effect of annealing upon the resistance was first noted by Foussereau and later studied by Gray and Dobbie. The relation between the time of annealing and the electrical resistance was investigated by us in the following manner. A number of tubes were constructed from a length of large and a length of small tubing and then placed in the electric furnace at 400°C. The tubes were withdrawn from the furnace singly after different intervals of time and when all had been removed were filled with mercury by distillation, placed in the water bath at 74.3°C and the resistance of each determined. The results of these measurements together with the results obtained with other tubes annealed for 1600 hours are given in Fig. 2. Certain measurements at 94.1°C indicated that a similar curve would have been obtained had these resistance measurements been carried out at that temperature.

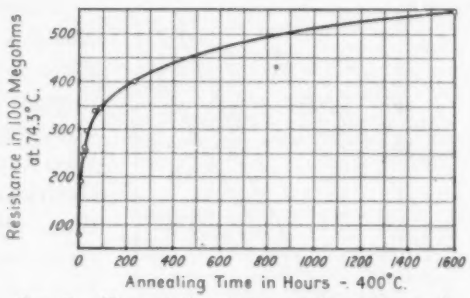


FIG. 2.—The relation between time of annealing and the electrical resistance.

The permanent nature of the change in the resistance which may be brought about by annealing was previously noted by Gray and Dobbie and we were able to confirm their observations. Thus resistance measurements on May 21, 1923 with tubes No. 84, No. 85, and No. 87, yielded for the specific resistances respectively 43.3, 42.9 and 38.9 $\times$ $10^8$ ohms. Similar experiments on tube No. 88 of the same series gave on Dec. 19, 1923 a value of 40.7 $\times$ $10^8$ ohms. The slight differences here shown are

[1] In this paper we are using the word annealed to designate a heat treatment at high temperatures. Usually we heated the tubes exposed to the atmosphere in an electric furnace at 400°C for many hours. The temperature varied slightly with changes in the line voltage.

[2] Warburg, *Wied. Ann.*, **21,** 622 (1884); Tegetmeier, *ibid.*, **41,** 19 (1890); LeBlanc and Kerschbaum, *Z. physik. Chem.*, **72,** 468 (1910); Schulze, *Ann. Physik*, **37,** 435 (1912).

due to experimental errors such as errors in the determination of the true dimensions of the glass.

**Temperature Coefficients**

The change in the resistance of the glass upon annealing was so marked that it seemed advisable to determine if the temperature coefficients of the resistance were similar in the two cases. For this purpose tubes were annealed by heating for 24 hours at 400°C. The results are given in Fig. 3; the values for the unannealed glass agree with those published by Holladay.[1] The change in the slope of the curve due to annealing, *i. e.*, the change in the temperature coefficient, might have been caused by a slight change in composition judging from Holladay's results. The resistance-temperature function does not change in form but only in the value of the constants.

A few measurements were made with a lead glass (PbO 52.9%) and these results are included in the diagram.

**Migration Experiments**

The purely electrical resistance measurements do not afford any positive clue as to the nature of the change which is induced in the glass by a proper heat treatment. A method of attack upon this phase of the problem may be based upon the electrical migration of silver into glass.

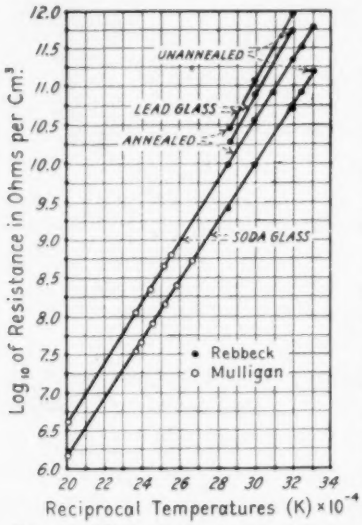


FIG. 3.—The relation between temperature and electrical resistance.

Schulze[2] has studied both the thermal diffusion and the electrical migration of silver into glass. He found that in the thermal diffusion the silver in the silver nitrate melt replaced the sodium in the glass and that both thermal diffusion and electrical migration took place at the same time. He also noted that some diffusion took place when the direction of the current was reversed. The diffusion phenomenon is, therefore, one that must be considered in connection with migration experiments. Provided that the diffusion phenomenon does not mask the migration effects, it should be possible by migration experiments to check our resistance measurements on annealed and unannealed glasses and to obtain some idea of the carriers of the current in these glasses. For this purpose are required the weights of the silver electrolyzed into the glass and the thicknesses of the layers produced. The weight of the

[1] Holladay, *Jour. Franklin Institute*, **195**, 229 (1923).

[2] Schulze, *Ann. Physik*, **40**, 335 (1913).

silver may be obtained if we know (1) the total increase in weight of the glass in the experiment, (2) the thermal diffusion blank. The weight increase may be directly observed by weighing the cleaned tube before and after the experiment. The thermal diffusion blank consists of two blanks: the blank due to thermal diffusion before and after electrolysis, and the blank during electrolysis. The former blank may be obtained from tubes immersed in the melt simultaneously with the tube under investigation. The latter blank can only be obtained by difference from the actual weights obtained and the weight calculated from the current measurements. The thickness of the silver layer may be easily determined with a microscope, since upon heating the glass containing the silver the layer becomes brownish in color and the boundary is quite sharply defined.

The details of a typical experiment are as follows: Two annealed and two unannealed tubes were cleaned by the method used by Schulze[1] and weighed. They were then filled with mercury by distillation in a good vacuum and placed in a bath of molten silver nitrate. One tube of each kind was then electrolyzed with mercury cathode at constant voltage. The duration of each stage of the process was noted and the current flowing observed with a precision potentiometer as in the resistance measurements.

TABLE I

| | Total time 185 minutes. Applied e.m.f. 108 volts | | | |
|---|---|---|---|---|
| Temperature 223–231°C. Time of electrolysis 142 mins. | Tube No. 307D unannealed electrolyzed | | Tube No. 309A annealed electrolyzed | Tube No. 305D unannealed not electrolyzed |
| Wt. silver in glass | 0.0809 g. | | 0.0313 g. | 0.0108 g. |
| Thermal diffusion blank before and after electrolysis | 0.0023 | | 0.0013[2] | |
| Total silver less T. D. blanks | | 0.1086 | | |
| Total silver for current | | 0.1052 | | |
| Probable T. D. blank during electrolysis | 0.0022 | | 0.0012 | |
| Layer thickness | 8.9% | | 4.6% | |
| Ratio silver electrolyzed into the tubes (unannealed to annealed) | | 2.66/1 | | |
| Ratio glass conductivities from current measurements | | 2.77/1 | | |
| Ratio conductivities from previous resistance measurements | | 2.75/1 | | |
| Ratio thickness of layers | | 1.9/1 | (thermal diffusion neglected) | |

[1] Schulze, *Ann. Physik*, **37**, 438 (1912).

[2] This value assumed from other experiments.

At the close of the electrolysis, the tubes were removed, cleaned and weighed. They were then heated in the flame of a Bunsen burner to bring out the color and the layers observed under the microscope. Experimental difficulties prevented the completion of any whole set of measurements, but from a number of partially completed series we were able to check the one nearly complete series given in Table I.

These results confirm our previous work which indicated a marked increase of resistance upon annealing. They provide no evidence in favor of the theory that sorbed gases and vapors are engaged in the conduction process.[1]

If the change in resistance induced by annealing arose from a decrease in the speed of the ions alone, the ratio of the thicknesses of the layers would have been equal to the ratio of the conductances. On the other hand, if the change were due to a decrease in the number of carriers, *i. e.*, a decreased ionization, then the layers would have been of equal thickness, but of different densities. The theory that the change is due to a decreased ionization is perhaps the logical one for a chemist to propose and has been tentatively suggested by Sutton and Silverman;[2] however, in the experiments quoted and in many others, the layer thicknesses were in the ratio of approximately 2/1, whereas the conductances were in the ratio of nearly 3/1. These facts lead us to believe that the major factor in the change must be a decrease in the speed of the ions, but that there is also a slight change in the number of carriers as well.

**Remarks on Annealing**

The resistance of the glass does not appear to be affected in any reasonable time at temperatures below 100°C, but at temperatures above 300°C allowance must certainly be made for changes due to annealing. Thus the estimates made by Schulze concerning the resistance of glass containing silver and the deduction of Kraus and Darby[3] relative to the ionization of glass at different temperatures may be affected by this source of error.

## Electrical Treatment

The true resistance of a piece of glass is obtained with direct current when the glass remains unaltered in composition during the time of the measurements. The ideal way to ensure that this will be the case would be to choose such electrodes that the same ions migrate into the glass on the one side as are migrating out of the glass on the other side during the time of measurement.

Even if the conditions just outlined cannot be fulfilled the time of mea-

[1] See Part I for further discussion of this point.

[2] Sutton and Silverman, *Jour. Amer. Ceram. Soc.*, **7**, 86 (1924).

[3] Kraus and Darby, *Jour. Amer. Chem. Soc.*, **44**, 2783 (1922).

surement may be so shortened that errors due to electrolysis may become negligible and the values obtained be independent of the direction of the current.

When the electrolysis has proceeded for some time, this latter statement does not hold and with a set-up in which the electrodes differ in character, such as the one used by us, the measured resistances are very dependent upon the direction of the current.

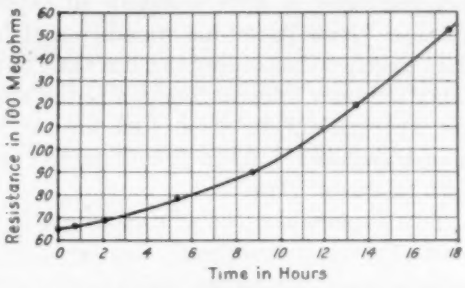


FIG. 4.—The change in the electrical resistance due to continued electrolysis with mercury anode.

When the current flows from the sodium hydroxide solution (mercury cathode) the apparent resistance changes but little during an extended electrolysis. Even after many hours, the total increase does not amount to more than a few per cent and small counter electromotive forces may be observed if the source of potential be removed from the circuit and the latter closed. These polarization voltages quickly fall to values which remain nearly constant for many hours. The latter values are dependent in magnitude upon the time of electrolysis and range from one to two volts. The glass in this case behaves somewhat as a storage battery. Brace[1] has recorded that he has observed similar effects with porcelain.

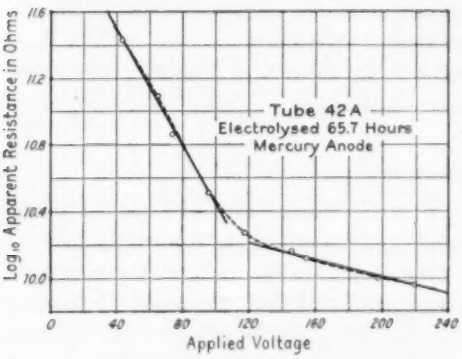


FIG. 5.—The relation between the apparent resistance and the applied voltage.

When the current flows in the reverse direction (mercury anode) the apparent resistance increases continuously as the electrolysis proceeds. In Fig. 4, the results of an experiment[2] at constant applied voltage with unannealed glass are given. These results were confirmed by two other independent experiments. The curve shows that, although the quantity of current passing through the glass in a unit of time becomes less as the electrolysis proceeds, the rate of change of the resistance with time appears to increase. The apparent resistance of a tube which has been electrolyzed for a long time

[1] Brace, *Trans. Amer. Electrochem. Soc.*, **33**, 205 (1918).

[2] The electrolysis was carried out at 74.3° with 110 volts.

with mercury anode is, however, a function of the applied voltage. The relation existing between the apparent resistance and the applied voltage for one tube[1] is shown in Fig. 5, in which the logarithm of the resistance is plotted against the applied voltage. The apparent resistance decreases as the voltage rises and for certain ranges of applied voltages, this apparent resistance is approximately an exponential function of the applied voltage. Now Poole[2] has found that at high voltages glass does not conduct electricity according to Ohm's law but that the logarithm of the resistance is nearly a linear function of the applied voltage. The gap between his experimental conditions and our own is perhaps too great to warrant an extrapolation but our results suggest that he may not have been dealing with unaltered glass.

Two explanations have been given for the change in resistance upon electrolysis just described. Schiller[3] tentatively suggests that there is a polarization phenomenon which is a function of the applied voltage, while the work of Warburg, LeBlanc and Kerschbaum, and Schulze[4] at higher temperatures seems to indicate that high resistant layers are the major factor. LeBlanc and Kershbaum were able to prepare glasses in which the conduction process was no longer ionic in character and in which the current was proportional to the square of the applied voltage.

We have a great many observations upon this phase of the subject and many of our results indicate that the behavior of glass under such conditions may be similar to that of some other dielectrics. The nature of the so-called absorption currents and residual currents is in fact the point in question. The present status of our work does not permit us to discuss this point at length, but we have many experiments which do not seem to be explained by the high resistant layer theory and which point fairly conclusively to a type of polarization phenomenon as an ultimate explanation.

## Summary

1. The relation between the thermal history and the electrical resistance of glass has been investigated. Curves are shown which indicate (1) the change of resistance with time of annealing and (2) the temperature coefficient of the resistances of annealed and unannealed glasses. From electrical migration experiments, using silver nitrate, the marked increase in the resistance which may be produced by annealing appears to be due more to a change in the mobility of the sodium ions than to a decrease in the number of these carriers.

[1] The tube was previously electrolyzed with 100 volts at 94.1°.

[2] Poole, *Phil. Mag.*, **42,** 501 (1921).

[3] Schiller, *Ann. Physik*, **74,** 105 (1924).

[4] Warburg, *loc. cit.;* LeBlanc and Kerschbaum, *loc. cit.;* Schulze, *Ann. Physik*, **37,** 435 (1912).

2. The apparent resistance of a glass sample may or may not increase markedly upon prolonged electrolysis depending upon electrode conditions. In the cases in which we observed great increases, the apparent resistance is a function of the applied voltage. Our results at 75° and 94°C tend to support the polarization theory of such increases at low temperatures rather than that based upon high resistant layers, but are as yet too few for a definite conclusion.

## Acknowledgment

Mr. Mulligan is at present the holder of one of the Bursaries granted by the Research Council of Canada and we wish in conclusion to express our appreciation of their assistance which has materially aided in the prosecution of this work.

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# ANALYSIS OF RECENT MEASUREMENTS OF THE VISCOSITY OF GLASSES

By Gordon S. Fulcher[1]

ABSTRACT

**Viscosity of Simple Soda-Silicate Glasses, 500° to 1400°C**

Comparison of the results given by English with those of Washburn, Shelton and Libman, indicates a discrepancy in the absolute values of $\log_{10}$ viscosity amounting to 0.6, those of Washburn *et al.*, being relatively too high. If correction for this is made, the isothermal curves of $\log_{10}$ viscosity as a function of soda content are smooth up to 50% $Na_2O$, showing no inflection. The observations as a function of temperature $T$ are all represented within accidental error by an equation of the type

$$\log_{10} \eta = -A + B \times 10^3 / (T - T_0)$$

where all three constants vary regularly with the composition.

**Change of Viscosity of Glass ($6SiO_2$, $2Na_2O$) due to Molecular Substitution of CaO, MgO and $Al_2O_3$ for $Na_2O$**

The effect is clearly brought out by plotting (from the results of English) the change of $\log_{10} \eta$ due to the substitution as a function of temperature. The curves each show a sharp bend at a temperature between 840° and 1050°C, which is designated the aggregation temperature $T_a$. If we divide these curves by the corresponding percentage substituted, we get curves for each oxide which are straight and parallel below the aggregation temperatures, the slopes (increase of change of $\log_{10} \eta$ per 100°C) being −0.056 (CaO), −0.055 (MgO), −0.018 ($Al_2O_3$) per per cent oxide substituted. For substitution of $\frac{1}{2}$ molecule the slopes are −0.325 (CaO), −0.23 (MgO) and −0.18 ($Al_2O_3$) per 100°. At the aggregation temperature the change of $\log_{10} \eta$ per per cent is a minimum, 0.03 to 0.06 for CaO, 0.12 for MgO, 0.07 for $Al_2O_3$.

**Evidence of Aggregation in Glasses, from Viscosity Measurements**

The sharp bends in the plots of change of $\log_{10} \eta$ due to substitution of an oxide for $Na_2O$, suggest the beginning of molecular aggregation at these temperatures. These aggregation temperatures are close to the devitrification temperatures, but the effect on the viscosity curves cannot be due to actual devitrification since it does not change with time. Taking the aggregation temperatures as equal to devitrification temperatures, additional isotherms are roughly sketched into the *equilibrium triangle of the system* $Na_2O$–$CaO$–$SiO_2$.

**Change of Viscosity of Glass ($4SiO_2$, $2Na_2O$) due to Substitution of $B_2O_3$ for $SiO_2$**

The change of $\log_{10} \eta$ (from the results of English) is plotted as a function of temperature, and also the change of $\log_{10} \eta$ per per cent $B_2O_3$. The curves are more complex than for the substitution for $Na_2O$.

## Introduction

To the glassmaker the viscosity of his glass, particularly at the higher temperatures, is of the greatest importance. The refining of glass depends on the rate at which the gas bubbles rise and this varies with the viscosity; the weight of the gather, the size of the gob fed through an orifice,

[1] Recd. March 20, 1925.

the distribution obtained in a blown article, the sharpness with which the glass takes the form of the mold, and the rate of annealing, each depend upon the viscosity of the glass through the corresponding range of temperature. Nevertheless until recently no accurate measurements have been made. During the past year, however, the results of two extensive, systematic and carefully made investigations have been published. S. English[1] studied the viscosity of several series of soda-lime, soda-magnesia and soda-boric oxide glasses at temperatures from 500° to 1400°C. Just previously Washburn, Shelton and Libman[2] obtained values for a series of soda-lime glasses for the range 800° to 1500°C. It seemed worth while to subject the data to a graphical analysis in order to correlate and compare the results of the two investigations and to get as much information as possible from them as to the variation of viscosity with temperature and with composition.

The method of measurement used in the two investigations is the same in principle. In both cases the glass was melted to a definite depth in a porcelain crucible held at the desired temperature by means of an electric resistance furnace, and the viscosity was measured by the rate at which a given torque, applied by means of a weight hung on a silk thread, rotated a rod mounted on ball bearings which carried a stirrer which was carefully centered and immersed to a definite depth in the glass. The furnaces were somewhat different, that of English having been relatively quite long while that of Washburn *et al.*, closely fitted the crucible and was supplied with independent heating wires in the lid as well as on the sides and bottom and was controlled by means of three thermocouples, while English used only one. The stirrer used by English was cylindrical and covered with an iridio-platinum sheath, while Washburn *et al.* used a carefully formed porcelain stirrer with a relatively small neck where it passed through the surface of the glass. Both pieces of apparatus appear to have been carefully calibrated and the precision obtained in each case seems to be about the same. A careful reading of both articles did not suggest any definite reason why the results obtained in the two investigations should not be given equal weight.

For temperatures from 500° to 750°C, it is impossible to use the above method, so English obtained values for the viscosity from measurements of the rate of elongation of a rod or thread under a given applied load.

In the following analysis, the various glasses will be designated by the authors' numbers, followed by an E or a W, to indicate English or Washburn *et al.*

[1] S. English, *J. Soc. Glass Tech. Trans.*, **7**, 25 (1923) and **8**, 205 (September, 1924).

[2] E. W. Washburn, G. R. Shelton and E. E. Libman, Univ. of Illinois Eng. Exp. Station, *Bull.* **140**, 74 pp. (April, 1924).

## 1. Sodium Silicate Glasses

Results are given for the following glasses:

| Glass | $Na_2O$, per cent | $R_2O_3$, per cent | RO, per cent | Loss ($H_2O + CO_2$), per cent | Ratio of $Na_2O$ to $SiO_2$ |
|---|---|---|---|---|---|
| 2W | 17.0 | 0.46 | 0.0 | 0.8 | 0.207 = 1/4.84 |
| 600E | 19.46 | .80 | .1 | ? | .244 = 1/4.1 |
| 1E | 25.34 | .42 | .2 | ? | .342 = 1/2.93 |
| 3W | 29.5 | 1 (about) | .1 | ? | .43 = 1/2.32 |
| 4W | 39.3 | 1 (about) | .1 | ? | .67 = 1/1.5 |
| 1W | 49.4 | 0.6 to 1.8 | .1 | 2.5 | 1.03 = 1/0.97 |

The data for 1E extend from 485° to 1310°C. When log $\eta$ ($\eta$ = viscosity) is plotted as a function of temperature (see English, Fig. 6)

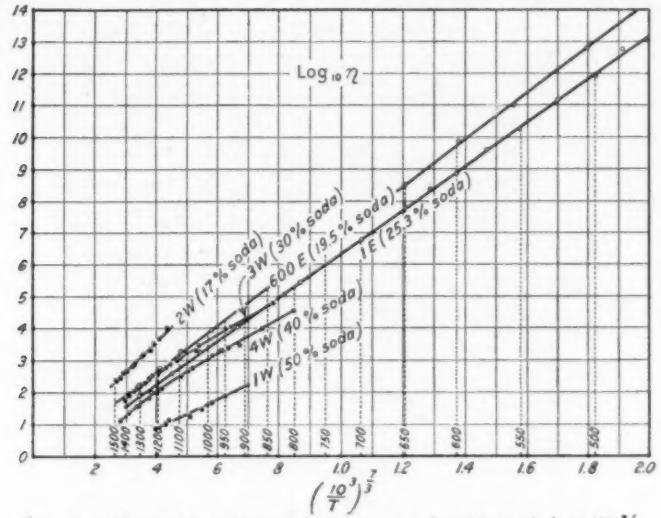


FIG. 1.—Observed values of $\log_{10} \eta$ as a function of $(10^3/T)^{1/3}$. Smooth curves drawn through experimental points.

a curve concave upward is obtained, log $\eta$ decreasing less rapidly the higher the temperature. Let us change the variables so as to get as near a straight line plot as possible. If log $\eta$ is plotted as a function of $1/T$, where $T$ is absolute temperature centigrade, a curve concave upward is still obtained. The concavity is less if $1/T^2$ is used, and it was found that log $\eta$ plotted as a function of $(1/T)^{1/3}$ gave practically straight lines both for 600E and 1E (see Fig. 1).[1] Therefore

$$\log \eta = -a + b\,(10^3/T)^{1/3}. \qquad (1)$$

[1] Slightly better agreement with a linear relation is obtained if we assume that there is a jog of 0.17 between the line through the points below 700° obtained by the elongation method, and the line through the points above 700°. If we subtract 0.17 from the values for the lower temperature the data for 1E are represented within experimental error (±0.03) by the equation (1E) $\log_{10} \eta = -0.40 + 6.66(10^3/T)^{1/3}$.

In Fig. 1 the results for glasses 1W, 2W, 3W or 4W have also been plotted and full lines have been drawn through the observations so as to represent them as closely as possible. The curves for 3W and 4W are definitely concave downward. But the most interesting fact brought out in this figure is the marked discrepancy between the E and W curves, not so much in the shape as in the absolute values. The 3W curve for 30% soda crosses the 1E curve (25.3% soda) at 850° and nearly touches the 600E curve (19.5% soda) at 1400°, while the 2W curve (17% soda) is farther above the 600E curve (19.5% soda) than the 4W curve (40% soda) is below it. If the results for a certain temperature, say 1200°, are plotted as a function of the ratio of soda to silica $r$, an irregular curve is obtained, as shown in Fig. 2*A* by the dotted line *abcde*.

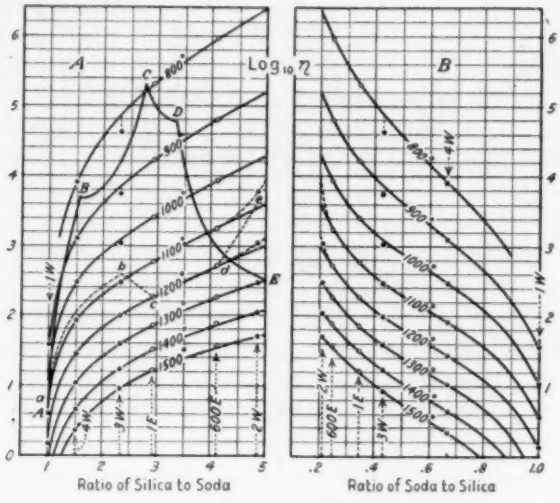


FIG. 2.—Value of $\log_{10} \eta$ as a function of composition for various temperatures.

Now it is possible, of course, that this dotted curve represents the real relation between viscosity and composition. The only other evidence we have is by Morey and Bowen[1] who recently determined the equilibrium diagram for soda and silica. The devitrification curve given by them shows corners at compositions 23, 26.5 and 39.2 per cent soda corresponding to ratios $r$ = 3.34, 2.77 and 1.55. On Fig. 2 the curve *ABCDE* shows log $\eta$ at the devitrification temperature as a function of $r$.

[1] Morey and Bowen; *J. Phys. Chem.*, **28,** 1174 (November, 1924). The devitrification temperatures plotted in Fig. 2 are as follows:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $r$ = | 0.97 | 1.55 | 1.94 | 2.77 | 3.03 | 3.34 | 4.85 |
| $T_d$ = | 1088° | 840° | 874° | 793° | 842° | 870° | 1280° |

There is no relation evident between curves *abcde* and *ABCDE*, and we must conclude that the viscosities of the sodium silicates are not influenced by any tendency to devitrification. Therefore until measurements on more compositions have been made we must assume that the curve showing the relation between log $\eta$ and $r$ is a smooth one.

Returning to curve *abcde*, it is evident that the two E values are relatively too low to fit in with the W values. It was found that when 0.6 is subtracted from each of the latter, all the values lie on the smooth curves shown of the full lines in Fig. 2, except the values for 2W for 1200° and below, which seem too high, indicating devitrification, and the values for 3W for 1000° and below which seem too low.

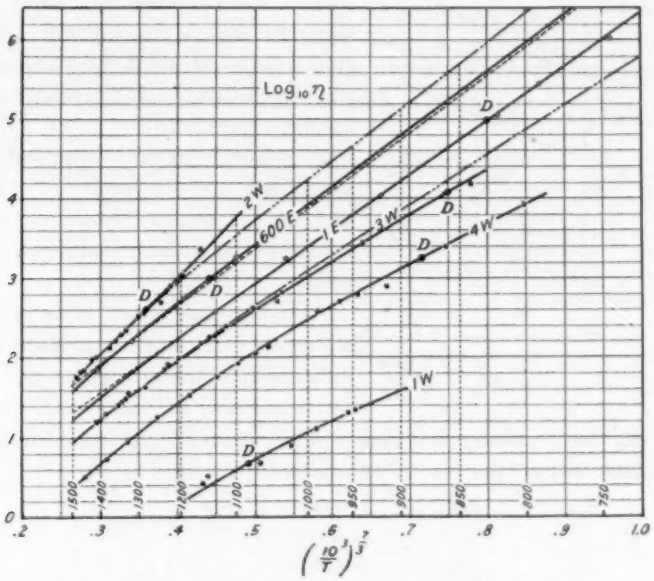


FIG. 3.—Values of $\log_{10} \eta$ as a function $(10^3/T)^{7/3}$ with values for W curves decreased by 0.60.

Figure 3 shows the same curves as Fig. 1, for temperatures above 750°, with the W curves displaced downward 0.6. The curves drawn with lines and dashes represent the smoothed values from Fig. 2 where these differ from the full line values. The dotted lines represent the straight lines as drawn in Fig. 1 for 600E and 1E.

It is of interest to note that the viscosity curves for both E and W glasses extend to temperatures below that at which they should begin to devitrify, without showing any bending, except 2W. (The devitrification parts are marked by *D* on Fig. 3.)

From the curves in Figs. 2 and 3, the relative values of the viscosity of any two sodium silicates between 800° and 1500° and for $r$ between 1 and 5 may be determined as accurately as the values upon which these curves are based, are known. But even if our curves give the relative values correctly, the absolute values are still uncertain because of the apparent discrepancy of 0.60 between the results of the two investigations. Since 0.60 is the logarithm of 4, this discrepancy means that the W viscosities are four times too large or the E values are four times too small or there are errors in both sets such that the ratio of the required correction factors is 4, for instance $^1/_2$ and 2. This conclusion emphasizes the importance of developing a reliable method of calibrating high temperature viscosity apparatus. If the absolute values for a standard glass at high temperatures were known, this glass could then be used in calibrating all such apparatus. It is suggested that future experimenters make a few runs with glasses having compositions approaching closely those of 1E, 600E and 3W so as to enable their results to be compared with those discussed in this paper.

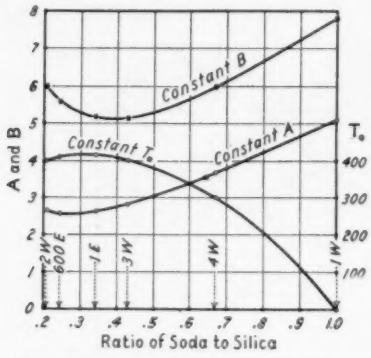


FIG. 4.—Constants in equation $\log_{10}\eta = -A + B \times 10^3/(T - T_0)$, as a function of ratio of soda to silica.

As to the mathematical representation of the curves, the data plotted in Fig. 3 indicate that the curves are not straight for temperatures above 1000° but bend downward; that is, above 100° log $\eta$ varies inversely as some higher power of the temperature than $^7/_3$. Equations of the form

$$\log \eta = A - B/T + C/T^2 \quad (2)$$
$$\log \eta = -A + BT + C/T^2 \quad (3)$$
$$\log \eta = -A + B \log T + C/T^2 \quad (4)$$
$$\log \eta = -A + B/(T - T_0)^2 \quad (5)$$

may be made to represent the results more or less closely but the three constant equation which seems to fit the results best is of the form

$$\log \eta = -A + B \times 10^3/(T - T_0) \quad (6)$$

This equation with the values of the constants given in Table II fits the experimental results for both 1E and 600E (corrected by subtracting 0.17 from the values for below 750°) within the accidental errors. For the other glasses the range of temperature is too small to determine $T_0$ accurately so values of $T_0$ were chosen which give values of log $\eta$ for 500°C consistent with the values for the E glasses. The constants were also adjusted so as to vary continuously with the soda-silica ratio (see Fig. 4).

TABLE II
CONSTANTS IN THE EMPIRICAL EQUATION (6) FOR SODA-SILICA GLASSES[1]

| Glass | Soda/silica | $A$ | $B$ | $T_0$ | Log $\eta$ at 500° (calc.) |
|---|---|---|---|---|---|
| 2W | 0.207 | 2.64 | 6.00 | 400° | 13.45 |
| 600E | .244 | 2.56 | 5.60 | 410 | 12.87 |
| 1E | .342 | 2.63 | 5.20 | 415 | 11.89 |
| 3W | .43 | 2.81 | 5.15 | 400 | 11.0 |
| 4W | .67 | 3.68 | 6.00 | 300 | 9.0 |
| 1W | 1.03 | 5.08 | 7.80 | 0 | 5.0 |

In Fig. 5 are plotted the values of log $\eta$ as a function of $10^3/(T-T_0)$. The observed values are indicated only for 1E, 600E and 2W; but for all the glasses the straight lines represent the smoothed values on the curves of Fig. 2 quite accurately. In the case of 2W the observed viscosity evidently increases too rapidly with decreasing temperature below 900°. This is probably due to crystallization.

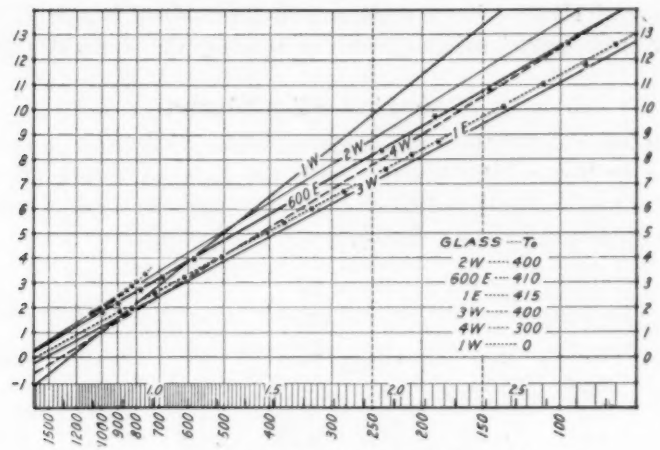


FIG. 5.—$\text{Log}_{10}\,\eta$ function of $10^3/(T - T_0)$.

Whether or not equations (1) and (6) have any physical significance, they are evidently useful for plotting in order to compare the results for different glasses or those obtained by different observers.

In two recent papers[2] LeChatelier states that when log (log $\eta$) is plotted as a function of $T$, two straight lines meeting at an obtuse angle are obtained for each glass. While such a plot may be convenient for interpola-

[1] The empirical equations correspond to the observed values of log $\eta$ corrected by subtracting 0.60 from all the W values and 0.17 from the E values obtained by the elongation method (below 750°).

[2] Henri LeChatelier, *Compt. rend.*, **1924,** pp. 517 and 718 (referred to in *Nature*, **114,** p. 731, November 15, 1924); *J. Soc. Glass Tech.*, **9,** 12 (March, 1925).

tion purposes, it should be evident that this equation is unlike that of any of the ordinary physical equations in that the shape of the curve obtained depends not only on the base of the logarithms used ($e$ or 10) but also on the units in which $\eta$ is expressed. For instance if the values of $\log_e(\log_e \eta)$ for temperatures 1000°, 1200° and 1400° are 2.130, 1.780 and 1.430 (approximately the values for 3W) the curve is a straight line; but the values of $\log_e(\log_e e^2\eta)$ are 2.3433, 2.0707 and 1.8212, the middle value being 0.0115 less than it should be if the relation is linear, corresponding to a difference of 9.6 per cent in $\eta$. The plot of $\log_e(\log_e \eta/e^2)$ curves the other way; the middle value is greater than it should be for a linear relation, the difference of 0.191 in $\log_e \eta/e^2$ corresponding to a difference of 21% in $\eta$. Any linear relation obtained in such a plot is therefore purely accidental and can have no physical significance. The positions of the inflections reported by LeChatelier would also shift more or less with the units employed, the shift being greater the nearer the angle of inflection is to 180°. The curves plotted in Fig. 5, however, show no indications of inflection. In the case of 1E the viscosity changes in the ratio of 1 to $10^{11}$, yet the results are represented within accidental error by the single straight line.

### 2. Soda-Lime-Silica Glasses

English investigated the series of glasses whose percentage compositions are given in Table III. Starting with the soda tri-silicate 1E ($Na_2O$, $3SiO_2$), CaO was substituted for $Na_2O$ molecularly in steps of about 0.1 molecule up to ($Na_2O$, CaO, $6SiO_2$).

TABLE III
PERCENTAGE COMPOSITION OF SODA-LIME-SILICA GLASSES (ENGLISH)

| Glass | CaO | $Na_2O$ | (CaO+$Na_2O$) | Equiv. $Na_2O$ | $SiO_2$ | Minor | Total |
|---|---|---|---|---|---|---|---|
| 1E | 0.21 | 25.34 | 25.55 | 25.57 | 74.05 | 0.38 | 99.98 |
| 3E | 2.61 | 23.00 | 25.61 | 25.80 | 74.08 | 0.37 | 100.05 |
| 4E | 3.81 | 21.50 | 25.31 | 25.59 | 74.07 | 0.42 | 99.80 |
| 5E | 4.50 | 20.78 | 25.28 | 25.61 | 73.78 | 0.72 | 99.78 |
| 6E | 6.26 | 19.38 | 25.64 | 26.00 | 73.18 | 1.40 | 100.22 |
| 7E | 7.45 | 17.20 | 24.65 | 25.21 | 74.41 | 0.94 | 100.00 |
| 8E | 8.16 | 16.00 | 24.16 | 24.77 | 74.99 | 0.66 | 99.81 |
| 9E | 9.36 | 14.88 | 24.24 | 24.94 | 74.96 | 0.86 | 100.06 |
| 10E | 10.38 | 14.22 | 24.60 | 25.37 | 74.59 | 0.96 | 100.15 |
| 11E | 11.68 | 13.02 | 24.70 | 25.57 | 74.93 | 0.86 | 100.49 |

**Percentage Substitution of CaO for $Na_2O$**

Since the percentage of $SiO_2$ is practically constant we may consider these a series of glasses with about 74.5% $SiO_2$ in which CaO is substituted for $Na_2O$, per cent for per cent. To bring out the effect of this substitution, the *change of* $\log_{10} \eta$ *due to substitution* is plotted in Fig. 6 as a function of the temperature for each of the glasses

3E to 11E. In getting these values correction was made for the variation of percentage of (CaO + $Na_2O$) by comparing with the results for a simple soda glass having a percentage of soda equal to the percentage of (CaO + $Na_2O$) (obtained by interpolation between 1E and 600E curves). The observed changes of $\log_{10} \eta$ are indicated by points connected by dashed lines. Although these dashed curves are somewhat irregular, they each show unmistakably a sudden bend at about 900° to 1000°C. Above this temperature, the change in log $\eta$ due to the substitution does not vary much with temperature though it shows a tendency to decrease with decreasing temperature. Below this temperature, however, the change in

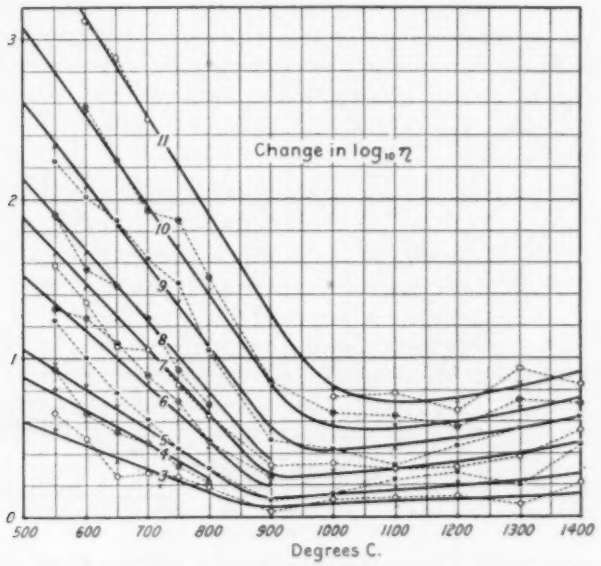


FIG. 6.—$\Delta \log_{10} \eta$ for various lime glasses as a function of temperature.

log $\eta$ increases approximately linearly with decreasing temperature. The full line curves were drawn with the aid of a plot of the change of $\log_{10} \eta$ at certain fixed temperatures as a function of the per cent CaO, so that they represent the results smoothed with respect to CaO variation as well as to temperature variation.

It is evident that the slopes of the low temperature parts of the curves of Fig. 6 increase with the percentage of CaO. If we divide each of the full line curves of Fig. 6 by the corresponding per cent CaO we obtain the curves of Fig. 7 which therefore give the *change in* $\log_{10} \eta$ *per per cent CaO substituted*. The low temperature parts are now parallel. While the observations are not accurate enough to prove that these curves must be

exactly parallel, yet the best smooth curves drawn through the observations lead to lines which are remarkably close to being parallel.

Now as to the physical interpretation of this result. Evidently as the soda-lime glass cools, at a temperature varying from 860° (for 2% CaO) to 1010°C (for 12% CaO) some process of molecular rearrangement must start which increases the rate at which the viscosity changes with decreasing temperature. It is natural to suppose that this is a process of molecular aggregation so we shall call the temperature at which this starts the *aggregation temperature.* These temperatures will be shown to be about those at which devitrification is to be expected. Devitrification was actually observed only in the case of glasses 10E and 11E and none

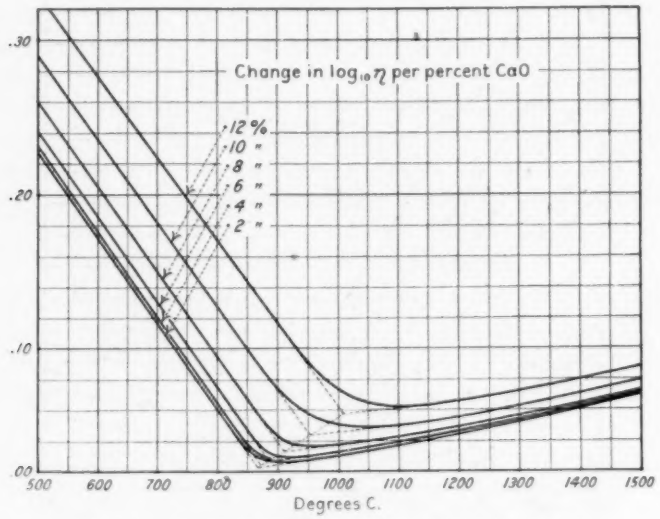


FIG. 7A —Percentage substitution of CaO for $Na_2O$.

of the recorded points (except perhaps 750–900° for 10E) relate to devitrified glass. When visible devitrification sets in, crystals grow steadily so that consistent readings cannot be taken. The molecular aggregations responsible for the change of slope of the viscosity curves of Fig. 6 must, therefore, be sub-crystalline, for while they begin to form at a temperature at which devitrification is to be expected, yet they seem to be in equilibrium (for less than 10 per cent CaO) and to give a definite viscosity at each temperature. The fact that the curves giving change of log $\eta$ per per cent CaO are parallel below 850° means that the *increase per degree of the change of log $\eta$ due to the substitution of CaO is proportional to the per cent of CaO substituted;* the shift of the line to the right with increasing per cent CaO is due to the shift of the aggregation temperature to higher values.

**Molecular Substitution of CaO for $Na_2O$**

The curves of Fig. 7A are for substitution of CaO for $Na_2O$, per cent for per cent, in a sodium silicate with about 74.5% $SiO_2$. In case of molecular substitution, since 56 gm. of CaO are molecularly equivalent to 62 gm. of $Na_2O$, the silica content does not remain constant but increases slightly, in fact from 74.05 for ($6SiO_2$, $2Na_2O$) to 74.93 for ($6SiO_2$, $1Na_2O$, 1CaO). Since increasing the silica content increases the viscosity, the changes in $\log_{10}\eta$ due to molecular substitution are somewhat greater than for percentage substitution. The smoothed results for the change of $\log_{10}\eta$ per per cent CaO for substitution of 0.2, 0.4, 0.6, 0.8 and 1

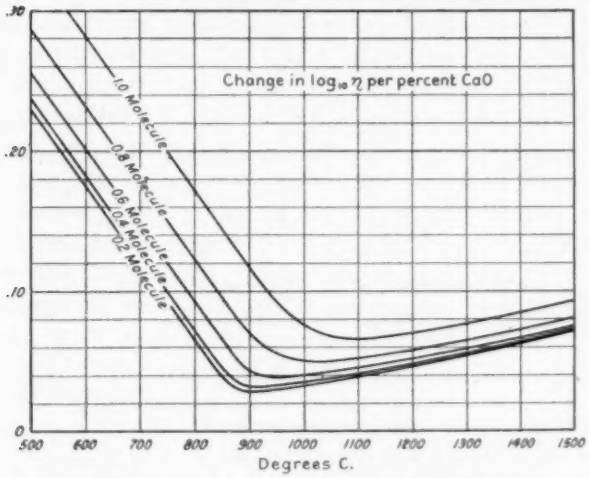


FIG. 7B.—Change in $\log_{10}\eta$ per per cent CaO, for molecular substitution of 0.2 to 1 molecule for $Na_2O$.

molecule of CaO in the soda-tri-silicate ($6SiO_2$, $2Na_2O$) are shown in Fig. 7B.[1]

The compositions of the corresponding glasses are given in Table IV.

The variation of the aggregation temperature with per cent CaO is shown in Fig. 8, for 25% ($Na_2O$ + CaO). The devitrification temperature for pure sodium-silicate with 25% $Na_2O$ is about 838° according to the curve of Morey and Bowen[2] while the value for the aggregation tempera-

[1] As shown in Table III, the equivalent $Na_2O$ (which is the amount of soda in the simple soda-silicate in which molecular substitution of a certain percentage of CaO will give a glass of the composition of the actual glass, and therefore determines the composition of the simple soda-silicate with which the actual glass is to be compared as to viscosity) is practically constant, as was intended in making up the glasses. The slight corrections necessary were made so as to reduce all to 25.34% equivalent $Na_2O$. The formula for equivalent per cent $Na_2O$ is $N' = (KC + N)/[100 + (K-1)C]$, where $C$ is per cent $Na_2O$, and $K$ is ratio of molecular weights of $Na_2O$ to CaO.

[2] *Loc. cit.*

TABLE IV

| Glass | $SiO_2$, per cent | $Na_2O$, per cent | CaO, per cent |
|---|---|---|---|
| $6SiO_2$, $2Na_2O$ | 74.05 | 25.34 | 0 |
| $6SiO_2$, 1.8 $Na_2O$, 2CaO | 74.23 | 22.85 | 2.3 |
| $6SiO_2$, 1.6 $Na_2O$, 4CaO | 74.40 | 20.4 | 4.61 |
| $6SiO_2$, 1.4 $Na_2O$, 6CaO | 74.58 | 17.9 | 6.93 |
| $6SiO_2$, 1.2 $Na_2O$, 8CaO | 74.75 | 15.4 | 9.26 |
| $6SiO_2$, 1.0 $Na_2O$, 1CaO | 74.93 | 12.8 | 11.63 |

ture from these viscosity measurements is 860°. The agreement is so close that one is inclined to attribute the small difference to the impurities present or to uncertainty in the determination of the aggregation temperature. The devitrification temperature of pure calcium silicate with 25% CaO is 1540° according to G. A. Rankine.[1] This point also seems to lie on the aggregation temperature curve extrapolated from 12% CaO. We may therefore conclude that the aggregate temperature given by the viscosity curve is the same as the devitrification temperature or slightly above it. However, it should be emphasized that aggregation does not seem to be the same as devitrification. It occurs promptly and reaches a limit which is a definite function of the CaO content whereas devitrification for low content of CaO, especially when alumina is present as impurity, may not occur unless the glass is held at the proper temperature for a long time and when it starts it increases with time so that successive viscosity measurements are not the same.

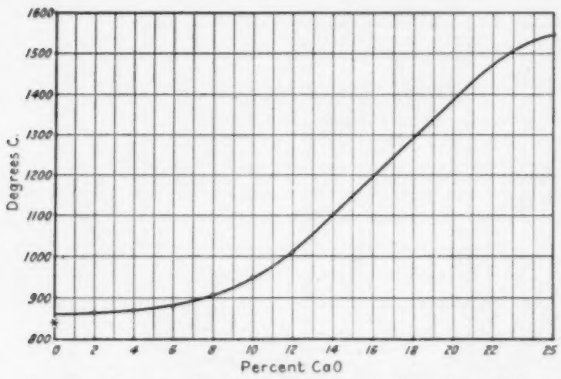


FIG. 8.—Aggregation temperature as a function of CaO.

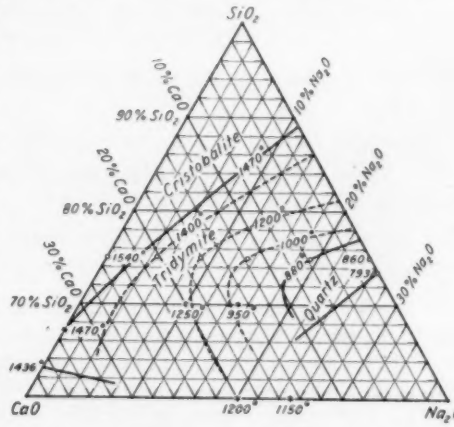


FIG. 9.—Equilibrium triangle for system $CaO$–$Na_2O$–$SiO_2$.

Part of the equilibrium tri-

[1] G. A. Rankine, *Amer. Jour. Sci.*, **39**, 5 (1915).

angle for the system $Na_2O$–CaO–$SiO_2$ is given in Fig. 9. The limits of the cristobalite and tridymite regions have been determined for calcium silicates and for sodium silicates but nothing is known about the interior of the triangle. Assuming that the aggregation temperatures given by the viscosity curves are the same as the devitrification temperatures, we have now for 75% $SiO_2$ points on the isothermal curves for 880° (boundary between quartz and tridymite), 1000° and 1200°. Also the points for 1400° and 1470° (boundary between tridymite and cristobalite) may be taken from Fig. 8. This allows us to sketch in roughly the isotherms as shown in Fig. 9.[1] Two points for 70% $SiO_2$ obtained from the curves of Washburn *et al.* (see Fig. 11 below) are also used in drawing these curves. The two points for 60% $SiO_2$, also obtained from Washburn *et al.*, probably lie outside the tridymite regions. This figure shows how viscosity and similar measurements may help in the determination of the isothermals of such systems.

Washburn *et al.* also determined the viscosity curves of a number of soda-lime silicates. Their results for the change of $\log_{10} \eta$ due to substitution of 10% and 20% CaO for $Na_2O$ in glasses with 60, 65, 70 and 75% $SiO_2$, are shown in Fig. 10. The dashed curves are for actual glasses, the full line curves are from the smoothed isotherm plots. It should be noted that since the change of $\log_{10} \eta$ is obtained by subtracting the value of $\log_{10} \eta$ for the sodium-silicate glass from that for the soda-lime-silica glass, this change is independent of the absolute values and is the same whether we subtract 0.60 from all the W values or not.

In Fig. 10A the curve obtained by English for 10% CaO and 75% $SiO_2$ is given for comparison. The corresponding W curve is evidently quite different, showing a maximum where the E curve has a minimum. Each of the W curves for 10% CaO except that for 70% $SiO_2$ shows no indication of a bend upward but rather a tendency to decrease with decreasing temperature below 100°. However in Fig. 10B, the curves for substitution of 20% CaO show bends corresponding to those of the E curves. The corresponding aggregation temperatures are indicated on the equilibrium triangle Fig. 9.

In Fig. 11 are plotted some W values for the change of $\log_{10} \eta$ per per cent CaO, together with the E curve for 10% CaO from Fig. 7. It is remarkable that the left hand straight parts of the curves for 70% $SiO_2$, 20%

[1] Note added May 1. Dr. Morey has recently shown me an equilibrium diagram he has prepared on the basis of determinations of the devitrification temperatures of many pure soda-lime silicates. The results will be ready for publication soon. His curve corresponding to Fig. 8 is below mine for less than 10 per cent CaO and above mine for higher percentages. The difference may be due to impurities present in the glasses used for viscosity measurements. Fig. 9 is found to be only a rough approximation, as was to have been expected.

CaO; 60% $SiO_2$, 20% CaO; 60% $SiO_2$, 15% CaO and 75% $SiO_2$, 10% CaO (English) all have about the same slope. The curve for 65% $SiO_2$, 20% CaO is anomalous. The increase of the change of $\log_{10} \eta$ per degree decrease of temperature seems then not only proportional to the per cent of CaO substituted but independent of the per cent $SiO_2$.

A striking difference between the E and W results, as shown in Fig. 11, is that above the aggregation temperatures the E curves slope up whereas the W curves slope down, so that at 1400° C the effect per per cent CaO of substituting 10% CaO is .07 according to English (75% $SiO_2$) and only .004 (70% $SiO_2$) according to Washburn *et al.* The W results also indicate that the effect at 1400° of substituting lime decreases with decreasing percentage of $SiO_2$ until for 60% $SiO_2$ it is practically zero.

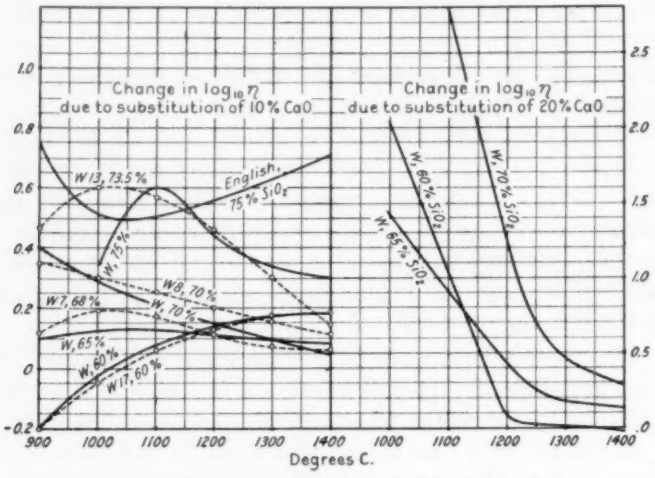


FIG. 10.—Percentage substitution of CaO for $Na_2O$.

### 3. Soda-Magnesia-Silica Glasses

English studied four glasses derived from the soda-tri-silicate 1E by molecular substitution of about 0.3, 0.6, 0.9 and 1.1 molecule of MgO for $Na_2O$. The percentage compositions are given in Table V.

TABLE V

| Glass | MgO, per cent | $Na_2O$, per cent | Equiv. $Na_2O$, per cent | $SiO_2$, per cent | $Fe_2O_3$, $Al_2O_3$ and CaO, per cent | Total, per cent |
|---|---|---|---|---|---|---|
| 1E | 0 | 25.34 | 25.34 | 74.05 | 0.59 | 99.98 |
| 26E | 2.49 | 22.12 | 25.61 | 75.00 | .26 | 99.87 |
| 329E | 5.09 | 18.26 | 25.39 | 76.30 | .74 | 100.39 |
| 32E | 7.46 | 14.55 | 24.98 | 78.66 | .93 | 99.80 |
| 390E | 9.30 | 11.76 | 24.80 | 78.28 | .91 | 100.25 |

Correcting for the slight variation of the values of the equivalent per cent $Na_2O$ (shown in the fourth column) from that for 1E, the *changes of* $log_{10}\ \eta$ *due to molecular substitution of MgO and* $Na_2O$ for the various percentages of MgO were determined. These are plotted in Fig. 12A. The full line curves correspond to the curves of Fig. 12B for the change of $log_{10}\ \eta$ per per cent MgO. The curves of Fig. 12B show the same type of bend at the aggregation temperature, the same increase of aggregate temperature with per cent substituted and the same constancy of slope below the aggregate temperatures, as the corresponding CaO curves. The experimental results are more irregular, however, and leave us in doubt as to whether the curves for temperatures above the aggregation temperature rise or fall with increasing temperature, and also whether the lines continue straight below 700° or curve down as indicated.

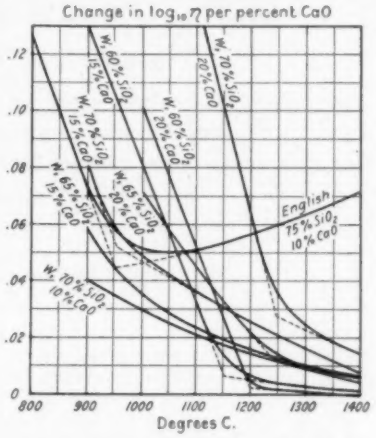


FIG. 11.—Substitution of CaO.

## 4. Soda-Alumina-Silica Glasses

The two glasses investigated by English had the compositions given in Table VI, being approximately produced by the substitution of .34 and .63 molecule of $Al_2O_3$ for $Na_2O$ in glass 1E.

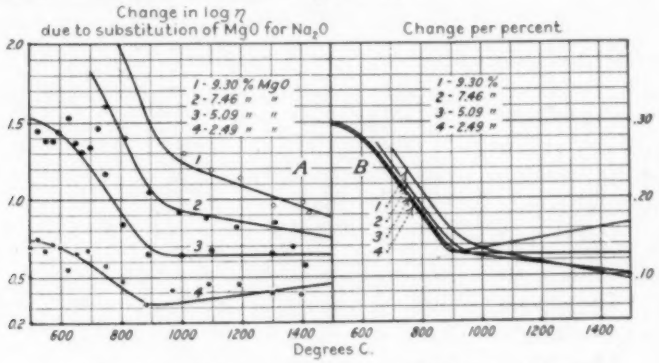


FIG. 12.—Molecular substitution of MgO for $Na_2O$.

TABLE VI

| Glass | $Al_2O_3$, per cent | $Na_2O$, per cent | Equiv. $Na_2O$, per cent | $SiO_2$, per cent | CaO and $Fe_2O_3$, per cent | Total, per cent |
|---|---|---|---|---|---|---|
| 1E | 0.24 | 25.34 | 25.48 | 74.05 | 0.35 | 99.98 |
| 443E | 6.85 | 20.62 | 25.52 | 72.05 | .20 | 99.72 |
| 446E | 12.69 | 15.28 | 24.39 | 71.56 | .31 | 99.84 |

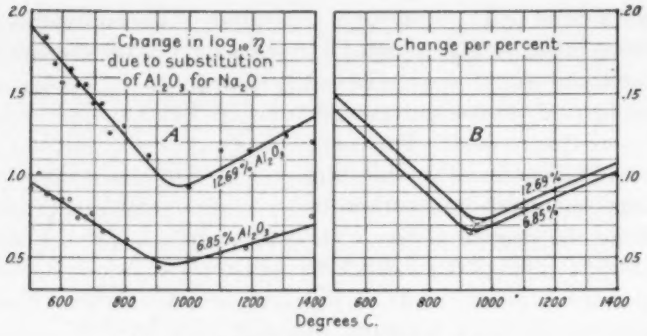


FIG. 13.—Molecular substitution of $Al_2O_3$.

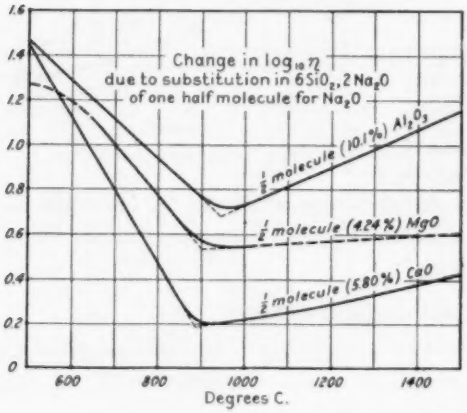
Change in log10 η due to substitution in 6SiO2, 2Na2O of one half molecule for Na2O
½ molecule (10.1%) Al2O3
½ molecule (4.24%) MgO
½ molecule (5.80%) CaO
Degrees C.

FIG. 14.—Molecular substitution of $^1/_2$ molecule.

The observed changes of $\log_{10} \eta$ due to molecular substitution of $Al_2O_3$ for $Na_2O$, corrected for the variation of equivalent $Na_2O$, are plotted in Fig. 13A. The full line curves correspond to the curves of Fig. 13B for the change of $\log_{10} \eta$ per per cent $Al_2O_3$. These curves of 13B are evidently similar to the corresponding curves for CaO and MgO. The straightness of the curves of Fig. 13A below 900° and the equality of slope of the curves of Fig. 13B below 900° are as striking as for CaO.

The relative effects of the substitution for $Na_2O$ in ($6SiO_2$, $2Na_2O$) of $^1/_2$ molecule of CaO, MgO and $Al_2O_3$ are shown in Fig. 14. The three curves are strikingly similar. The $Al_2O_3$ produces the greatest change of $\log_{10} \eta$ at all temperatures, the CaO produces the greatest increase in rate of set-

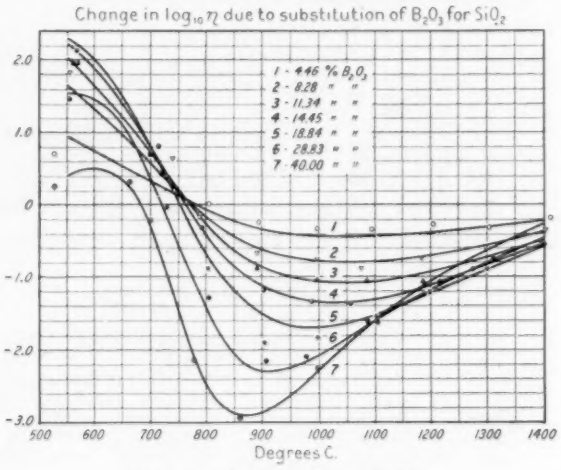


FIG. 15.—Substitution of $B_2O_3$.

ting at low temperatures, while the effect of MgO is intermediate in both respects. The slopes below 850° are 0.325 (CaO), 0.235 (MgO) and 0.178 ($Al_2O_3$) per 100°.

### 5. Soda-Boric Oxide-Silica Glasses

The seven glasses investigated by English were derived from the soda-silicate 600E ($4SiO_2$, $2Na_2O$) by the percentage substitution of boric oxide for silica—not for soda as in previous series—since boric oxide is acidic in character. The compositions are given in Table VII.

The change of $\log_{10} \eta$ due to substitution of $B_2O_3$ for $SiO_2$ is plotted in Fig. 15 for the seven glasses. The curves are quite different from those for substitution for $Na_2O$. Above 800° the change is a decrease. Figure 16 gives the change of $\log_{10} \eta$ per per cent $B_2O_3$ for 5, 10, 15, 20, 30 and 40% $B_2O_3$. These all show bends at 800° to 1000°, but these are not as sharp as in the case of substitution of $Na_2O$. The curves below 800° for 5 and 10% $B_2O_3$ are straight and parallel, but the curve for the higher percentage is on the low temperature side. Perhaps if molecular substitution had been adopted instead of percentage, the curves might have been more similar to each other and to those for molecular substitution of $Na_2O$.

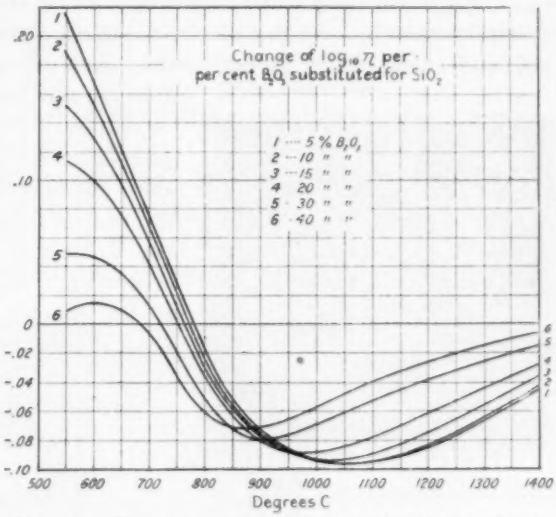


FIG. 16.—Change per per cent due to substitution of $B_2O_3$.

TABLE VII

| Glass | $B_2O_3$, per cent | $SiO_2$, per cent | ($B_2O_3$ + $SiO_2$), per cent | $Na_2O$, per cent | Minor per cent | Total per cent |
|---|---|---|---|---|---|---|
| 600E | 0 | 79.84 | 79.84 | 19.46 | 0.92 | 100.22 |
| 601E | 4.46 | 74.22 | 78.68 | 19.78 | 1.21 | 99.67 |
| 602E | 8.28 | 71.56 | 79.84 | 18.76 | 1.18 | 99.78 |
| 603E | 11.34 | 68.39 | 79.73 | 18.92 | 1.22 | 99.87 |
| 604E | 14.45 | 64.72 | 79.17 | 19.95 | 0.92 | 100.04 |
| 605E | 18.84 | 61.28 | 80.12 | 18.93 | 0.93 | 99.98 |
| 606E | 28.83 | 50.04 | 78.87 | 20.36 | 0.91 | 100.14 |
| 607E | 39.99 | 35.22 | 75.21 | 23.71 | 1.07 | 99.99 |

CORNING GLASS WORKS
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# OBSERVATIONS ON "HAIRLINES" IN SHEET IRON ENAMELS[1]

By J. E. Hansen and Gordon S. Lindsey[2]

ABSTRACT

Hairlines in sheet iron enamels may be caused either by under-firing of the ground coat enamel, or by "cold spots" on the ware when the cover enamel is fired. The defect may be prevented by properly firing the ground coat enamel, and by proper arrangement of the ware on the firing supports in the furnace.

By "hairlines" in sheet iron enamels, the authors refer to that defect which appears in sheet iron enamels applied by the wet process, and which is characterized by very fine black lines in the cover coat enamel, where the dark under-coat, either ground coat or dark colored edging enamel, shows through the cover enamel in a "hairline" formation. These hairlines usually appear in a more or less parallel conformation, but may spread out radially into a fan-shaped figure. This defect is sometimes called crazing, but wrongly so.

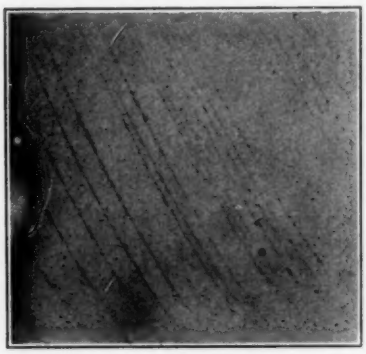

Fig. 1.—Typical example of hairlines.

Crazing is characterized by fine *cracks* in the enamel, which appear while the enamel is cooling, or some time after it is cool. "Hairlines," however, are simply *lines* in the enamel, not cracks, and appear during the firing or fusing of the enamel.

A typical example of hairlining such as appears on stove parts is shown in Fig. 1. This piece of ware has a ground coat, a black edging enamel, and two coats of white enamel. The hairlines on this piece appeared during the firing of the second coat white enamel, but they sometimes appear

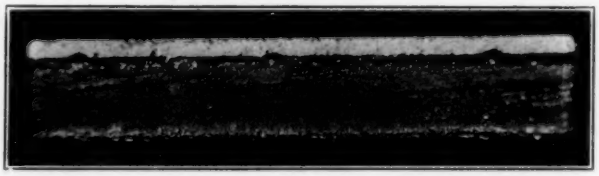

Fig. 2.—Cross-section of enamel ware, showing hairlines as raised ridges in undercoat of enamel.

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[1] Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, February, 1925. (Enamel Division.)

[2] Industrial Fellows of the Mellon Institute of Industrial Research of the University of Pittsburgh, Pittsburgh, Pa.

in the first white coat, and in a few instances have been visible in the black edging enamel.

A cross-section of a piece of enamelware showing these hairlines is given in Fig. 2. This shows the dark undercoats of enamel raised up in a ridge into the white enamel, coming so near the surface that the black ridge shows through as a dark hairline.

Hairlines are known to have appeared on almost all classes of sheet iron enamelware, including hollow ware, signs, table tops, stove parts, and other products.

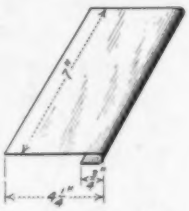

FIG. 3.—Type of test piece used.

## Observations

Various conditions under which hairlining has appeared have been observed by the authors, and in trying to arrive at an idea of the cause of such defects, and a possible remedy, certain trials were made to purposely cause hairlines in the enamel.

Standard test pieces of 22 gage Armco iron, 5 x 7 inches, were cut and one edge bent over as shown in Fig. 3 to roughly approximate a gas stove shelf with a rolled edge. Thirty of these pieces were properly cleaned and pickled, and ground coat enamel was applied. Fifteen pieces were fired at 1600°F for four minutes, while fifteen were fired for three minutes at the same temperature. All the trials fired for four minutes were fully matured, as judged by the color of the ground coat, while those fired for three minutes were slightly underfired, but would have passed the usual factory inspection as properly fired.

FIG. 4.—Showing hairlines in underfired enamel over the rolled edge of the sample.

When cool, these pieces were sprayed with a thin coat of "black edge enamel," which was then fired at 1600°F for one and one-half minutes, at the end of which time the enamel had a good gloss.

Two coats of white enamel were applied, edges being brushed back on

each coat, leaving a 1/4-inch black edge. Both coats of white were fired for two minutes at 1500°F. No hairlining was visible to the naked eye in any of the trials after the first coat of white was fired.

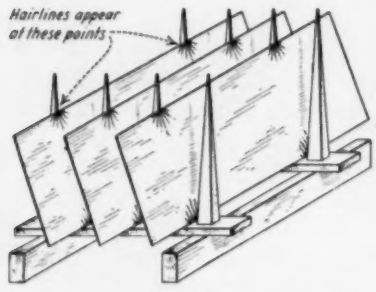


FIG. 5.—Showing hairlines of the type caused by cold firing supports.

After firing the second coat of white enamel, the trials were again examined. In the lot of fifteen pieces which had been fired for four minutes in ground coat, there was only one piece showing hairlining. In the lot of fifteen pieces fired for only three minutes in ground coat, nine pieces showed quite a few hairlines, while two others showed traces of hairlines. The hairlines were for the greater part immediately over the "rolled-over edge" of the trial piece, where the double thickness of metal which had to be heated in the furnace had contributed even more to the underfired condition of the enamel on that portion of the piece. Fig. 4 shows a portion of one of these pieces showing hairlines.

This portion of the experimental work checks closely the results obtained in a plant making enameled signs, where hairlining was encountered on a circular sign of a diameter of about three feet. It had been the plant practice to fire these signs three on a load in all firings, and about one-third of the signs showed hairlining in the cover enamel. On a few trial runs, careful record was kept of the position of each sign in the enameling furnace, and it was observed that it was the sign which had been fired in the cooler end (the door end) of the furnace which showed the hairlines. On the assumption that it was the less fired ground coat from the cool end of the furnace which later caused this trouble, the plant practice was changed so that two signs were fired on a load in ground coat enamel, and three signs as usual in all following

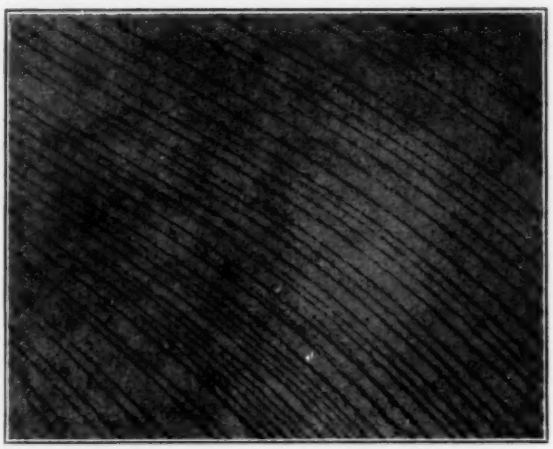

FIG. 6.—Hairlines caused by placing cold block of iron under the sample when cover enamel was fired.

coats. With this change in firing practice, almost all the hairlining disappeared.

Hairlining sometimes also appears in the corners of broiler pans in stove work, where the ground coat enamel has not properly drained away. This heavy deposit of ground coat is then usually not fired down properly, and hairlines show up in that region in the later coats of enamel.

Hairlines have also been encountered in several enameling plants on "double faced" flatware, which, because of the necessity of avoiding firing-pin marks, had to be fired on racks against which the ware was leaned, as shown in Fig. 5. These racks are of rather rugged construction, and although preheated in the furnace, they lose considerable heat before they can be loaded with ware and put back into the furnace. Consequently the supports against which the ware leans are somewhat cold, and heat up more slowly than the ware itself. Hairlines often show up in the enamel, at the point indicated in Fig. 5.

FIG. 7.—Hairlines in ground coat caused by placing cold block of iron under ware when cover enamel was fired.

In the discussion on hairlining at the 1924 meeting of the Enamel Division of this SOCIETY at Atlantic City, it was brought out that one hollow-ware enameling plant had experienced hairlining on that portion of the body of a coffee pot which was in close proximity to the handle of an adjacent coffee pot, as the ware was placed on the firing points. A different arrangement of the ware in the furnace, affording a wider spacing between each pot and the handle of the adjacent pot, eliminated the hairlines.

The authors duplicated this type of hairlining in an experimental way by placing a cold block of wrought iron between the firing points, directly underneath and close to the enameled pieces being fired, leaving about $^1/_4$ inch clearance. When firing ground coat with this chunk of cold iron underneath the ware, the enamel was slightly underfired at that spot, but not enough so to cause hairlining in the cover coat enamel, if the latter was fired in the usual manner.

However, if the cold piece of iron was placed beneath the ware when the cover enamel was fired, the latter was found to be badly hairlined. These hairlines are shown in Fig. 6.

Several pieces which were made to hairline by placing the cold iron

near the ware, also showed hairlines on the back side, that is, in the ground coat itself. Such a case is shown in Fig. 7. The peculiar part of this feature is that the hairlines on the reverse side of the piece run at right angles to the hairlines on the other side of the piece. No explanation is offered for this behavior.

## Summary

These trials show that there are at least two conditions under which hairlines will appear in enamels, namely, from an underfired ground coat enamel, and from "cold spots" caused by contact with, or close proximity of the enameled ware to cold objects as it is fired in the furnace.

The underfired ground coat may be the result of too short a firing time, too low a firing temperature, or of too thick enamel, in which case the problem resolves itself into properly setting up the enamel before dipping and firing.

The remedies to be suggested are quite obvious.

Proper firing of the ground coat will eliminate much of the hairlining from the underfiring factor. This may entail firing smaller loads of ware, to insure that it is all properly fired. In the case of ware having rolled edges, or double thicknesses of metal which absorb heat more slowly than other sections, it might be advisable to remove the ware from the furnace for a few seconds after it has reached red heat and allow the thin sections to cool, and then run it back into the furnace until the ground coat is fully matured. Likewise, firing the ground coat at a slightly lower temperature than usual for a somewhat longer time would allow the heavier parts of the ware to become properly fired without danger of badly overfiring the balance of the ware.

The elimination of cold firing supports, or placing the ware in a different manner in the enameling furnace, should eliminate hairlining due to unequal heating in the finish coats of enamel.

# A STUDY OF THE FACTORS INVOLVED IN THE SPALLING OF FIRE CLAY REFRACTORIES WITH SOME NOTES ON THE LOAD AND REHEATING TESTS AND THE EFFECT OF GRIND ON SHRINKAGE[1]

By M. C. Booze and S. M. Phelps[2]

ABSTRACT

Of the three factors, elasticity, coefficient of expansion and rate of temperature change, which affect spalling, the former is by far the most important. Only small differences are found between fire clay mixtures of widely varying structure and composition in the rate at which they change in temperature under like conditions of heating. The coefficient of expansion varies directly with the silica content and differences in this respect of large order were found. However, the spalling on the particular mixtures tested varied almost inversely as the coefficient of expansion. This apparent discrepancy is explained on the basis of greater elastic properties of the brick which had high expansions. The elasticity may be varied between wide limits and is sufficiently important as to overbalance the effect of greater expansion. This property is accordingly the one upon which efforts directed toward the development of non-spalling brick should be centered. It was discovered that a plastic deformation could be obtained at as low a temperature as 635°C. This gives the effect of elasticity and undoubtedly has considerable influence on spalling at the higher temperature ranges.

Results are given for a number of load tests which show clearly the importance of hard firing. The secondary expansion of brick made from Pennsylvania flint clay is shown to be influenced by the temperature of reheating, as well as its rate.

Detailed results showing the effect of grind and firing on the finished size of the brick included in the investigation are also given.

This study suggested itself through a consideration of the relation of spalling to the physical properties of fire clay refractories. It was known that such factors as hard and soft firing, coarse and fine grinding, introduction of grog or calcine, replacement of plastic clay by flint clay, open and dense firing clays, and to some extent the chemical composition were of considerable importance in accelerating or retarding spalling. It was not known, however, how variations in these factors affected individual properties of the refractories, nor the relative importance of those physical properties which govern spalling.

The stresses in a brick obviously arise from unequal expansion, which is in turn due to temperature differences of adjoining parts. If the brick is sufficiently elastic, the stresses due to differential expansion will merely produce a readjustment of the individual particles without causing fracture. Should the amount of expansion be enough, however, to cause the elastic limit and ultimate strength to be exceeded, breakage will take place.

It is evident that resistance to spalling can be increased by decreasing

[1] Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, February, 1925.

[2] Industrial Fellows, Multiple Industrial Fellowship of the Refractories Manufacturers Association, Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh, Pa.

the coefficient of expansion, and by increasing the elasticity, strength and heat conductivity. A spalling formula based on these factors is possible of development, but its value and accuracy would be most questionable. This investigation will have served its purpose if it indicates the relative amount of variation of the different factors which may be produced in practical ways and the corresponding effect upon the finished product.

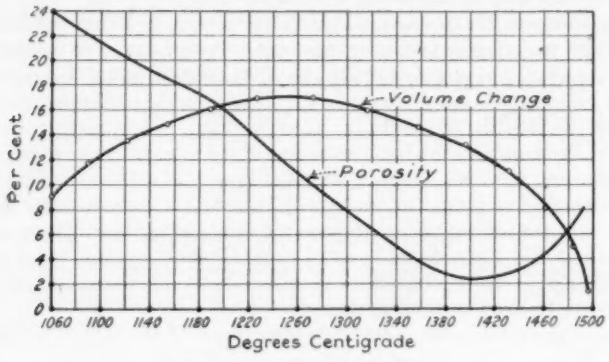


FIG. 1.—"K" plastic clay.

Such information is necessary in order that investigations on the production of a non-spalling brick may be conducted in an efficient manner.

In the past it has been exceedingly difficult to obtain accurate information on the behavior of various classes of fire clay refractories in industrial furnaces. Because of inconsistencies and discrepancies in reports made by various observers, it has not been possible to reach intelligent conclusions from service data. In addition to spalling, breakage may occur from the fact that the brick are improperly laid and subjected to bending stresses or from pinching off of the inner ends when the face of the lining expands. In some cases the brick or refractory shapes have been laid up dry or only loosely bonded and broken pieces fall out more readily than would be the case with better construction. In one instance hand made and relatively uneven shapes were laid dry in an arch with large, open joints and spalled badly because of the exposure of several faces to the heat.

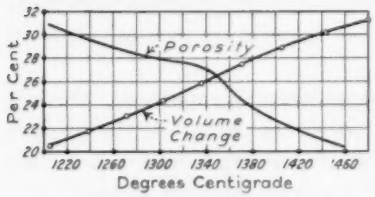


FIG. 2.—"W" plastic clay.

In some oil-fired furnaces a rapid disintegration of the refractories takes place. It is not known whether this is due to spalling or to some peculiar effect of the oil. The bungs of malleable iron furnaces are sup-

posed to furnish a typical example of spalling conditions and yet service reports are most conflicting. Tests have shown that the bung brick are often subjected to an enormous initial stress from the set screws used to hold them in the frame and it is reasonable to suppose that this stress may be increased to the crushing point by the normal thermal expansion. Under conditions such as have been described, it is difficult to study this cause for failure and accordingly laboratory tests must be largely relied upon in the development of brick with true low spalling tendencies.

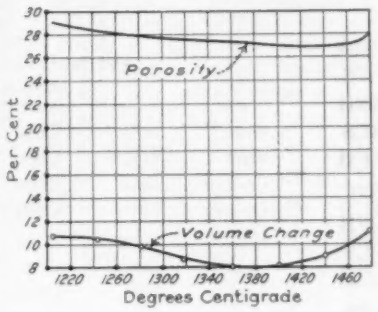


FIG. 3.—"M" flint clay.

## Preparation of Test Pieces

As it was highly desirable to keep the investigation within the bounds of practical limits, the aid of a fire brick company was obtained in preparing the samples. The Kier Fire Brick Company, through its president, S. M. Kier, gave the fullest coöperation in this respect and aside from having the pieces manufactured for this investigation, gave other advice and assistance which has been most valuable.

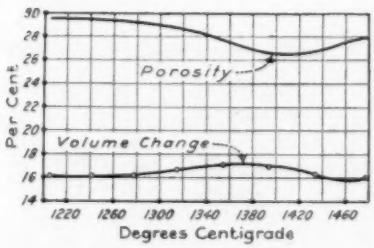


FIG. 4.—"S" flint clay.

Table I identifies the various samples as to grind, firing, composition and method of manufacture. Screen analyses of the green mixtures are given in Table II, chemical composition of the clays used in Table III, and the results of firing tests in Table IV. These firing properties are also shown graphically in Figs. 1, 2, 3, 4 and 5.

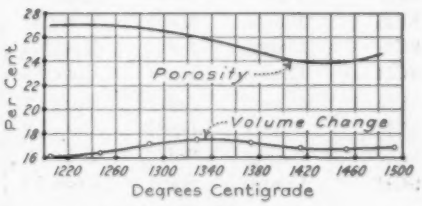


FIG. 5.—"D" flint clay.

The mixtures from 1 to 9 inclusive were prepared by grinding the various batches in a wet pan, sufficient mud from each batch for the specimens of coarse grind being taken out at the proper time and the balance in the pan then further ground for the samples of fine grind. In this way, the composition was kept the same for all samples in one lot. The mud was molded into 9-inch brick and cylindrical rods approximately 10 inches long by $1^1/_{16}$ inches in diameter, the latter being for coefficient

of expansion measurements. The brick were not repressed after molding in order that their density and structure would be like that of the rods.

TABLE I

IDENTIFICATION OF MIXTURES TESTED

| Mark | Grind | Firing | Method of manufacture | Composition |
|---|---|---|---|---|
| 1FS | Fine | Soft | Cone 3 | Soft mud 100% "K" clay |
| 1FH | Fine | Hard | Cone 12 | |
| 1CS | Coarse | Soft | Cone 3 | |
| 1CH | Coarse | Hard | Cone 12 | |
| 2FS | Fine | Soft | Cone 3 | Soft mud 80% "S" flint; 20% "K" plastic |
| 2FH | Fine | Hard | Cone 12 | |
| 2CS | Coarse | Soft | Cone 3 | |
| 2CH | Coarse | Hard | Cone 12 | |
| 3FS | Fine | Soft | Cone 3 | Soft mud 80% "S" flint; 20% "W" plastic |
| 3FH | Fine | Hard | Cone 12 | |
| 3CS | Coarse | Soft | Cone 3 | |
| 3CH | Coarse | Hard | Cone 12 | |
| 4FS | Fine | Soft | Cone 3 | Soft mud 80% "D" flint; 20% "K" plastic |
| 4FH | Fine | Hard | Cone 12 | |
| 4CS | Coarse | Soft | Cone 3 | |
| 4CH | Coarse | Hard | Cone 12 | |
| 5FS | Fine | Soft | Cone 3 | Soft mud 80% "D" flint; 20% "W" plastic |
| 5FH | Fine | Hard | Cone 12 | |
| 5FS | Coarse | Soft | Cone 3 | |
| 5FH | Coarse | Hard | Cone 12 | |
| 6FS | Fine | Soft | Cone 3 | Soft mud 80% "M" flint; 20% "K" plastic |
| 6FH | Fine | Hard | Cone 12 | |
| 6CS | Coarse | Soft | Cone 3 | |
| 6CH | Coarse | Hard | Cone 12 | |
| 7FS | Fine | Soft | Cone 3 | Soft mud 80% "M" flint; 20% "W" plastic |
| 7FH | Fine | Hard | Cone 12 | |
| 7CS | Coarse | Soft | Cone 3 | |
| 7CH | Coarse | Hard | Cone 12 | |
| 8FS | Fine | Soft | Cone 3 | Soft mud 80% calcined "S" flint; 20% "K" plastic |
| 8FH | Fine | Hard | Cone 12 | |
| 8CS | Coarse | Soft | Cone 3 | |
| 8CH | Coarse | Hard | Cone 12 | |
| 9FS | Fine | Soft | Cone 3 | Soft mud 70% "M" flint calcined; 10% "K" plastic calcined; 20% "K" plastic raw |
| 9FH | Fine | Hard | Cone 12 | |
| 9CS | Coarse | Soft | Cone 3 | |
| 9CH | Coarse | Hard | Cone 12 | |
| 10H | Medium | Hard | Cone 12 | Auger machine repressed 71% "M" flint; 29% "K" plastic |
| 10S | Medium | Soft | Cone 3 | |
| 11H | Medium | Hard | Cone 12 | Hand made 70% "M" flint raw; 4% "M" flint calcined; 26% "K" plastic raw |
| 11S | Medium | Soft | Cone 3 | |

TABLE II

SCREEN ANALYSES OF GREEN MIXTURES MADE WET ON STANDARD SIEVES

| Mixt. | On 4-mesh screen | Through 4 on 10 | Through 10 on 20 | Through 20 on 40 | Through 40 on 60 | Through 60 on 80 | Through 80 on 100 | Through 100-mesh screen |
|---|---|---|---|---|---|---|---|---|
| 2F | 0 % | 5.7% | 17.7% | 15.0% | 6.4% | 3.7% | 1.5% | 49.0% |
| 2C | 28.5 | 24.7 | 10.4 | 7.7 | 3.4 | 1.9 | 0.9 | 22.4 |
| 3F | 0 | 5.5 | 14.9 | 30.2 | 7.7 | 4.5 | 2.1 | 35.0 |
| 3C | 20.5 | 26.6 | 10.8 | 8.0 | 4.0 | 2.4 | 1.2 | 26.4 |
| 4F | 0 | 8.7 | 21.7 | 14.4 | 4.9 | 2.9 | 1.4 | 45.8 |
| 4C | 30.5 | 20.6 | 7.9 | 6.2 | 2.6 | 1.7 | 0.9 | 29.5 |
| 5F | 0 | 9.5 | 22.2 | 15.5 | 5.8 | 3.9 | 2.3 | 40.8 |
| 5C | 38.9 | 17.6 | 7.6 | 4.7 | 2.8 | 1.8 | 1.1 | 25.4 |
| 6F | 0 | 8.0 | 20.0 | 11.4 | 6.3 | 3.9 | 2.1 | 48.0 |
| 6C | 19.3 | 20.4 | 9.6 | 7.9 | 4.0 | 2.5 | 1.5 | 34.7 |
| 7F | 0 | 6.2 | 16.9 | 14.3 | 6.7 | 3.7 | 2.4 | 53.9 |
| 7C | 14.3 | 24.6 | 11.4 | 8.5 | 4.6 | 3.2 | 1.8 | 41.5 |
| 8F | 0 | 2.18 | 14.3 | 23.5 | 10.2 | 4.6 | 2.8 | 42.3 |
| 8C | 21.9 | 19.7 | 12.6 | 15.1 | 4.6 | 2.2 | 1.0 | 22.9 |
| 9F | 0 | 4.9 | 18.8 | 17.2 | 8.2 | 4.0 | 2.2 | 44.6 |
| 9C | 7.7 | 22.5 | 17.8 | 13.4 | 5.5 | 3.0 | 1.5 | 28.4 |
| 10 | 0 | 17.5 | 17.5 | 12.0 | 4.8 | 2.6 | 1.2 | 44.2 |
| 11 | 2.0 | 23.7 | 13.3 | 9.9 | 4.4 | 2.3 | 1.1 | 32.2 |

TABLE III

CHEMICAL ANALYSES AND FUSION POINTS OF CLAYS INCORPORATED IN SPECIMENS TESTED

| | "D" Flint clay | "S" Flint clay | "M" Flint clay | "K" Plastic clay | "W" Plastic clay |
|---|---|---|---|---|---|
| $SiO_2$ | 50.61 | 53.64 | 45.69 | 56.65 | 65.25 |
| $Al_2O_3$ | 45.33 | 42.35 | 46.34 | 36.33 | 29.46 |
| $TiO_2$ | 2.44 | 2.09 | 3.34 | 2.95 | 2.30 |
| $Fe_2O_3$ | 0.77 | 1.12 | 2.73 | 1.79 | 2.07 |
| CaO | 0.26 | 0.35 | 0.29 | 0.35 | 0.28 |
| MgO | 0.10 | 0.19 | 0.21 | 0.66 | 0.28 |
| Alkalis | 0.24 | 0.17 | 1.12 | 1.23 | 0.29 |
| Fusion point, cone | 33–34 | 33–34 | 33 | 30–31 | 32 |

TABLE IV

FIRING PROPERTIES OF CLAYS

| Clay | | | "W" Plastic clay | "K" Plastic clay | "S" Flint clay | "M" Flint clay | "D" Flint clay |
|---|---|---|---|---|---|---|---|
| Drying shrinkage | | | | 19.5% | 8.8% | 8.9% | 9.1% |
| Water of plasticity | | | | 19.4 | 17.4 | 16.4 | 17.4 |
| Fired porosity: | | | | | | | |
| Cone | 6 | 1205°C | 31.0% | See | 29.5 | 29.1 | 27.0 |
| | 8 | 1275 | 28.6 | figures | 29.2 | 28.4 | 26.9 |
| | 10 | 1325 | 27.5 | below | 28.5 | 27.7 | 25.9 |
| | 12 | 1370 | 24.5 | | 27.2 | 27.4 | 25.2 |
| | 16 | 1460 | 20.5 | | 27.6 | 27.1 | 23.9 |
| | 18 | 1480 | 19.3 | | 27.8 | 28.0 | 24.6 |

TABLE IV (*Continued*)

| Clay | "W" Plastic clay | "K" Plastic clay | "S" Flint clay | "M" Flint clay | "D" Flint clay |
|---|---|---|---|---|---|
| Volume shrinkage: | | | | | |
| Cone 6 | 20.5 | | 16.1 | 10.7 | 16.1 |
| 8 | 23.1 | | 16.1 | 10.3 | 16.6 |
| 10 | 24.9 | | 16.9 | 8.5 | 17.5 |
| 12 | 27.7 | | 17.2 | 8.1 | 17.3 |
| 16 | 30.2 | | 16.0 | 9.8 | 16.8 |
| 18 | 31.3 | | 16.2 | 11.0 | 16.8 |

"K" PLASTIC CLAY

| Cone | Temperature | Volume change | Porosity |
|---|---|---|---|
| . | 1060°C | 9.1% | 24.0% |
| . | 1100 | 12.4 | 21.6 |
| 1 | 1160 | 14.9 | 18.2 |
| 3 | 1205 | 16.0 | 17.6 |
| 5 | 1250 | 18.4 | 10.5 |
| 9 | 1312 | 15.9 | 4.8 |
| 13 | 1357 | 14.6 | 4.0 |
| 15 | 1415 | 12.4 | 2.3 |
| 17 | 1455 | 4.6 | 4.5 |
| . | 1495 | 1.6 | 8.3 |

Firing was accomplished in a periodic kiln according to the usual plant practice. The soft and hard firings were obtained by placing in different positions in the kiln.

## Laboratory Tests

### Coefficient of Expansion

For these determinations, a furnace was designed and built by the junior author. A detailed drawing of this is given in Figs. 6 and 7. It was originally intended to make the determinations at temperatures as high as 1350°C and it was for that reason that a gas fired furnace was used. It was found, however, that the fused silica rods which connected the test specimen with that part of the apparatus which was used for indicating expansion, softened so badly above 1125°C that the test could not be conducted at higher temperatures. This condition was also noted by Mer-

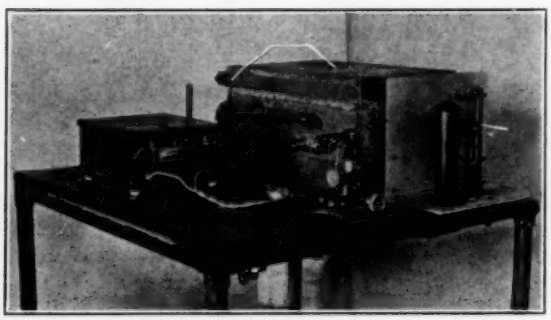

FIG. 6.

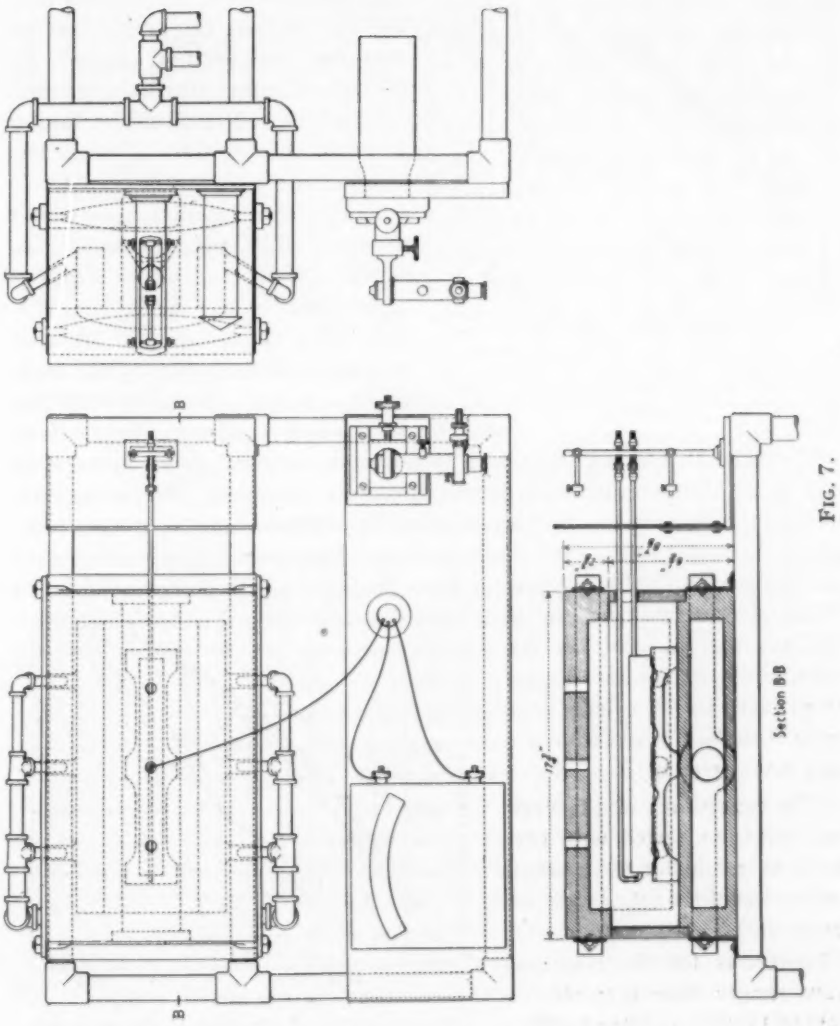


FIG. 7.

ritt[1] and reported at about the same time these tests were being conducted. A partial analysis made on one of the rods which deformed badly showed a silica content of only 96.3%, which may explain the premature softening.

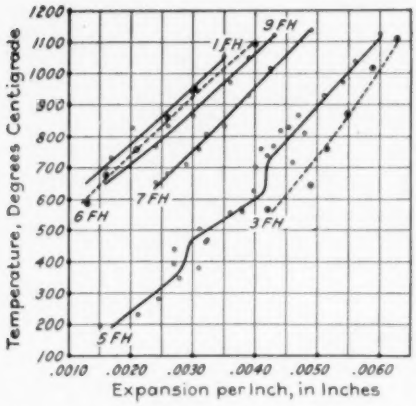


FIG. 8.—Reversible expansion of various clay mixtures.

On account of this softening, the expansion was not determined during the heating-up period, except over low temperature ranges. At the highest temperatures the thermal contraction was obtained by taking an initial reading and allowing the temperature to fall rather rapidly to a point where the silica glass would be rigid. The cooling schedule between 1000°C and 500° required approximately five hours, the furnace then being allowed to cool down over night before a final reading was taken. By using high bag walls and down-draft in the furnace, with the flame playing on a bed of granular material, good combustion and a uniform temperature distribution were obtained. While the temperature range for the test was limited by softening of the quartz rods, errors from this cause were minimized by taking readings only during the cooling period. The expansions were read to $^1/_{1000}$ inch by means of a Filar micrometer eyepiece in the microscope, and, as the maximum expansion varied from .040 to .075 inch, the error from lack of sensitiveness was not extreme.

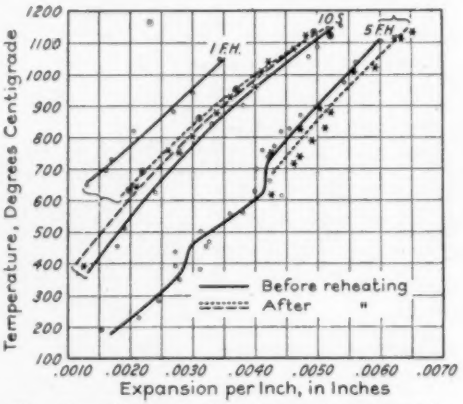


FIG. 9.—Effect of reheating on the reversible expansion of clay mixture.

The expansions of the various mixtures tested with corrections made for the normal expansion of the silica rods are given in Figs. 8, 9, 10 and 11. The results for the temperature ranges from 0 to 800°C, 800 to 1100°C and 0 to 1100°C are also given in Table V.

The various mixtures differed to a greater extent in this property than was expected and also showed lower average coefficients than previously

[1] "Thermal Expansion of Fused Quartz," *Jour. Amer. Ceram. Soc.*, **7** [11], 803 (1924).

TABLE V

AVERAGE COEFFICIENTS OF EXPANSION[1]

| Mixt. | 0 to 1100°C | 800°C to 1100°C | 0 to 800°C |
|---|---|---|---|
| 1FH | 2.6 | 3.0 | 2.2 |
| 1FH reheated | 3.9 | 4.1 | 3.1 |
| 7CH | 4.0 | 4.2 | 3.7 |
| 7FH | 4.1 | 4.2 | 3.3 |
| 7FH reheated | 5.7 | 5.6 | 6.1 |
| 5FH | 5.7 | 5.4 | 5.9 |
| 5FH | 5.8 | 5.4 | 6.1 |
| 5FH reheated | 5.7 | 5.6 | 6.1 |
| 5FH reheated | 5.9 | 5.7 | 6.3 |
| 3FH | 6.4 | 5.8 | 7.3 |
| 6FH | 3.1 | 3.37 | 2.4 |
| 10S reheated | 4.0 | 4.0 | 3.7 |
| 10S reheated | 4.5 | 5.0 | 3.3 |
| 10S | 4.2 | 4.2 | 4.1 |
| 10H | 4.1 | 4.2 | 3.4 |
| 9FH | 3.5 | 3.6 | 2.8 |

published results have indicated. The amount of expansion between 0° and 650°C bears a relation to the silica content and is also governed to a small degree by the temperature of firing. The effect of silica on the expansion is shown in Fig. 11. The only result not falling on this curve was obtained on 1FH which was made entirely from plastic clay and which probably contained a much larger proportion of glass than the other samples. The effect of firing temperature is shown in Fig. 9, in two cases the expansion being increased by harder firing and decreased in a third. The effect of successively higher firing temperatures has been shown by Houldsworth and Cobb,[2] who obtained values both lower and higher than that of the original sample. The lowest value of all was obtained when the test piece was fired at an extremely high temperature and which in all probability produced a large amount of glass.

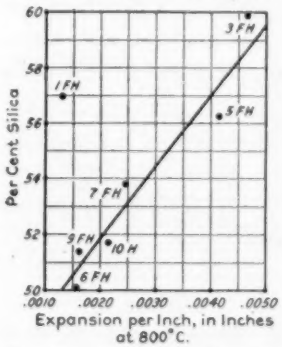


FIG. 11.—Effect of silica on the reversible expansion.

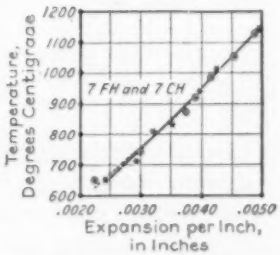


FIG. 10.—Effect of grind on the reversible expansion.

From the results shown graphically in Fig. 10 it is apparent that the grind has no effect on the thermal expansion.

Instead of the value 0.0000075 which has ordinarily been used in com-

[1] To get correct values, multiply figure given by $10^{-6}$.

[2] "The Reversible Expansion of Refractory Materials," *Jour. Amer. Ceram. Soc.*, **6**, 645–662 (1923).

puting the expansion for furnace design, values from 0.000004 to 0.000006 should be used for brick with silica contents varying from 50 to 60%, the low value being used for the low silica content.

**Diffusivity or Rate of Temperature Change**

While the heat conductivity is of importance in determining the temperature gradient within a body, the property which is desired here involves the specific heat and density as well. During the heating or cooling the maximum temperature gradient will be greater than when equilibrium is reached, due to the heat capacity of the body. Since it is the temperature difference which determines the amount of stress with a given coefficient of expansion, it is obvious that the factor which should be determined in this investigation is one of temperature difference with the body in an unsaturated condition.

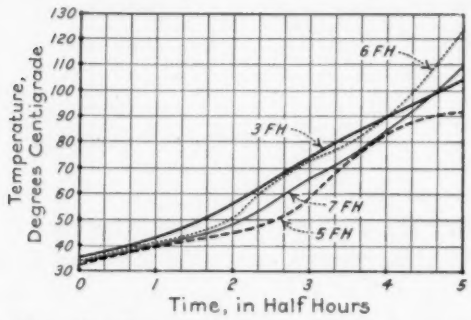


FIG. 12.—Rate of temperature increase as result of heat transmissions through 8 inches of brick, with hot end at 1050°C.

In making this determination several 9 x $4^1/_2$ x $2^1/_2$-inch brick were built into a panel, each brick being separated from the adjoining one by a $1^1/_4$-inch layer of Sil-O-Cel brick and all joints made tight with a plastic insulating cement. In this panel the $2^1/_2$ x $4^1/_2$-inch faces of the test brick were exposed, holes being drilled in the opposite ends to a depth of one inch and these filled with mercury. An open top, gas-fired furnace, whose horizontal cross-section was somewhat larger than the panel of test brick was partially filled with granular refractory material and this heated to a uniform surface temperature of 1000°C by the "surface combustion" principle. The test panel was then placed over the furnace and temperatures taken at intervals on the cold ends of the brick by means of thermometers placed in the mercury wells. These temperatures are given in Table VI and are shown graphically in Figs. 12 and 13.

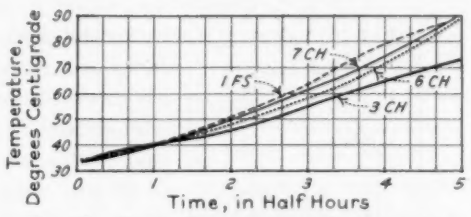


Fig. 13.—Rate of temperature increase as result of heat transmission through 8 inches of brick with hot end at 1050°C.

By reference to these data, it will be seen that the differences between the various mixtures are quite small. The finely ground brick show slightly

TABLE VI

DIFFUSIVITY OR RELATIVE RATE OF TEMPERATURE INCREASE OF FIRE CLAY BRICK

| Identification number | Beginning of test | 1/2 hour heating | 1 hour heating | 1 1/2 hour heating | 2 hours heating |
|---|---|---|---|---|---|
| 3FH | 35.5° | 43.7° | 56° | 74.2° | 88.7° |
| 7CH | 33.5 | 41.5 | 49.5 | 62.2 | 74.7 |
| 6FH | 34.2 | 43 | 50.7 | 74.0 | 92 |
| 1FS | 33.7 | 42.7 | 48.5 | 63.7 | 79 |
| 5FH | 32.7 | 39.5 | 45.7 | 58.5 | 73 |
| 6CH | 33.8 | 42 | 47.5 | 58.8 | 72 |
| 3CH | 34.3 | 41.3 | 46 | 55.2 | 64.7 |
| 7FH | 33.5 | 40.5 | 49.5 | 66.2 | 84.2 |
| 10H | 33.5 | 41.7 | 48.2 | 61.0 | 74 |
| 10S | 33.2 | 41.2 | 48.2 | 55 | 74 |

higher temperatures at the cooler ends than do those of coarse grind. No comparison was made between hard and soft fired samples, those included here being the ones upon which the whole investigation was largely centered.

While it would have been advisable to have made the temperature determinations at various depths in each brick had time permitted, it is not probable that the temperature gradients would have differed materially.

The samples tested represented rather wide extremes in porosity, that marked 1FS having a porosity of 15% and 5FH 26%. The test pieces, accordingly, were of greater variation in structure than would normally be found in commercial products and since the temperature differences were small it does not seem that the structure is of very much importance as far as heat efficiency is concerned in choosing brick to be used for checkers in regenerators.

**Elasticity**

The apparatus used for these determinations is shown in Fig. 14. The test pieces used were $9 \times 4\frac{1}{2} \times 2\frac{1}{2}$-inch brick, and in each test the specimen was clamped rigidly on one end in the machine and a torque applied at the other by means of weights and a lever. The angle of deflection was read by means of a telescope sighted on mirrors fastened to each end of the brick and which reflected the image of a radial scale fixed at a distance of $28\frac{1}{2}$ inches from the center of the brick. By this means it was possible to read the angle of rotation to within 0.0082 of a degree, or a relative motion of the brick of 0.00054 inch at a distance of $2\frac{1}{4}$ inches from the center and on points 6 inches apart or the distance between the mirrors. Readings were taken at two temperatures, heating of the specimen being accomplished by nichrome coils and the temperature measured by inserting a thermocouple to a depth of 2 inches in a hole drilled in one end along the center line.

The data obtained in this test are given in Table VII. The results are extremely interesting not only in showing very great differences in elasticity, but also in pointing out the effect of temperature on the elastic prop-

erties and in establishing the fact that plastic and permanent deformation takes place at surprisingly low temperatures. This is clearly indicated by the figures in the table and could readily be noted on some of the specimens after they were tested and removed from the apparatus. The stress required to produce this low temperature deformation varied from 75 to 180 pounds per square inch at a temperature of 635°C. This is greater than that which would ordinarily arise in furnaces due to the weight load to which they are subjected. Where the conditions are not such as to bring about an undue amount of settling, the property of having plastic flow at low temperatures may be advantageous. In the case of spalling this softening gives the effect of elasticity and the particles within the refractory body may move under the spalling stresses without cracking taking place and thus the upper limit of the temperature range over which spalling will occur will be determined to a large extent by the softening temperature. Where the brick in a furnace lining or roof are held rigidly in place they are subjected to compressive stresses when heated up due to their thermal expansion and this may cause failure due to pinching or crushing. If, however, they soften sufficiently to flow, the chances for failure are considerably lessened. The early softening which is referred to here and which has been detected in the elasticity test is apparently not one in which all of the clay deforms. It seems rather to be a condition where a small amount of glass which is holding the individual particles together has its viscosity lowered sufficiently that it will give under a stress less than that required to produce rupture. In determining the elasticity as it affects spalling over any temperature range, it is necessary to know the amount that the brick can be strained before rupture takes place. In many of the tests which were conducted here the amount of strain prior to rupture could not be determined due to the softening which took place. With materials of very high viscosity plastic deformation may take place

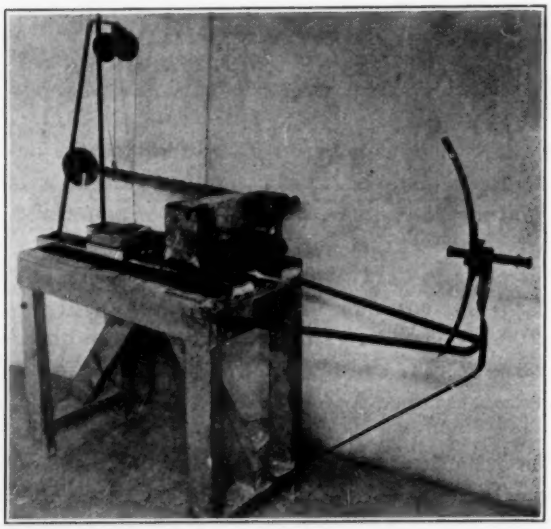

FIG. 14.

TABLE VII

ELASTIC AND PLASTIC DEFORMATION OF VARIOUS FIRE CLAY MIXTURES

| Mixt. | Temp. | Weight[1] | Deflection on scale[2] | Elastic deformation | Plastic deformation |
|---|---|---|---|---|---|
| 3FH | 635°C | 24 lbs. | 1 1/2 | 1 | 1/2 |
| 3FH | 635 | 30.35 | 2 | 1 | 1 |
| 3FH | 725 | 24 | 2 1/4 | 2 1/4 | 0 |
| 3FH | 725 | 62.15 | 7 | 5 1/2 | 1 1/2 |
| 3FH | 725 | 68.8 | 8 1/2 and broke | .. | .. |
| 3CH | 635 | 5 | 1 1/4 | 1/4 | 1 |
| 3CH | 635 | 12.5 | 8 | 4 1/4 | 3 3/4 |
| 3CH | 725 | 7.5 | 3 | 3 | 0 |
| 3CH | 725 | 12.5 | 10 | 7 | 3 |
| 3CH | 725 | 18.75 | 30 | 13 1/2 | 16 1/2 |
| 7FH | 635 | 30.65 | 2 1/4 | 2 | 1/4 |
| 7FH | 725 | 30.65 | 4 1/4 | 3 | 1 1/4 |
| 7CH | 635 | 9 | 2 | 2 | 0 |
| 7CH | 635 | 24 | 3 1/4 | 2 3/4 | 1/2 |
| 7CH | 635 | 30.65 | 4 1/2 | 3 3/4 | 3/4 |
| 7CH | 725 | 6.35 | 2 1/4 | 1 | 1 1/4 |
| 7CH | 725 | 13.0 | 17 | 5 | 12 |
| 5FH | 800 | 24 | 4 1/2 | 3 | 1 1/2 |
| 5FH | 800 | 30 | 55 | 10 1/2 | 44 1/2 |
| 10S | 700 | 11 | 0 | 0 | 0 |
| 10S | 700 | 41 | 7 | Not taken | |
| 10S | 800 | 11 | 9 | 3 | 6 |
| 1FS | 635 | 12.75 | 1 | 1/2 | 1/2 |
| 1FS | 635 | 19.15 | 2 3/4 | 1/4 | 2 1/2 |
| 1FS | 730 | 12.75 | 1 3/4 | 0 | 1 3/4 |
| 1FS | 730 | 24.0 | 40 | 0 | 40 |
| 9FH | 635 | 24.0 | 1 1/2 | 1 | 1/2 |
| 9FH | 725 | 24.0 | 2 1/4 | 1 | 1 1/4 |
| 9FH | 725 | 30.35 | 2 3/4 | 1 1/4 | 1 1/2 |
| 9FH | 725 | 68.0 | 3 1/2 | 1 3/4 | 1 3/4 |
| 9FH | 725 | 74.35 | Broke | | |

under the slow application of stress, while a shock may produce fracture. Considering the fact that in these tests permanent deformation took place within less than a minute after the application of the torque and also that there would be few practical cases where cooling would take place with sufficient rapidity to produce spalling within that time, it seems very probable that spalling would not occur at temperatures above that at which softening is apparent.

It is possible that the disintegration in some oil fired furnaces which has already been mentioned offers an exception to the statement just made. Oil flame temperatures are as a rule very high and the flame may either

[1] The weight as given was applied on the end of a 36-inch lever as shown in Fig. 14.

[2] One division on the scale corresponded to an angle of rotation of .0328 degree.

flutter or move about within the combustion chamber in a manner which is not characteristic of coal firing.

Since the radiation varies as the fourth power of the temperature, any change in intensity of the flame will be reflected immediately in the temperature of the wall and a thin layer on the inner surface of the refractory lining will be heated and cooled not only a large number of times, but with great rapidity. Although the temperature is ordinarily high enough that the refractory skin which is affected should be comparatively soft, the sudden changes may produce enough of a shock to cause cracking.

Since the temperature affects the true elasticity as well as the softening, a complete investigation on any one type of product should include elasticity measurements over the whole temperature range from room temperature up to the point of softening, as this will determine the range over which spalling is important. With these data and temperature graphs for a refractory wall or lining, it would also be possible to predict with a fair degree of accuracy the depth at which cracking would occur. However, time would not permit of enlarging the investigation to this extent.

In studying the figures given in Table VII, it should be kept in mind that it is the maximum elastic deformation regardless of the weight applied that is of importance in spalling. The amount of plastic deformation is, however, governed by the amount of stress.

Comparisons of the coarse and fine grinds are especially interesting. In addition to showing extreme differences in their elastic properties, the greater ease with which the coarse mixtures take on plastic deformation is also very evident. The elastic deformation was at a minimum on mixtures 1FS and 9FH, both of which were high in dense firing, plastic clay.

## Discussion of Combined Data on Coefficient of Expansion, Elasticity and Rate of Temperature Change as Affecting Spalling

In order to check the results of the investigations which have been described, a number of the brick were spalled by heating one end at 1400°C for 15 minutes and then cooling in a blast of air for a like period. This was continued until each brick had lost 20% or more of its original weight. Three bricks of each kind, after being reheated at 1400°C for 5 hours, were also subjected to the regular water dip spalling test.[1] The latter test was made for general information and the results are not applicable to the other data obtained on brick which had not been reheated. All of these results are shown in Table VIII.

It is apparent that there are considerable differences between the lots tested. In the air spalling test the poorest results were obtained on the

[1] C38–21T, American Society for Testing Materials, p. 297. 1922 Tentative Standards.

number 1 and 9 mixtures and the best on number 5 and 7. Mixtures 3, 6 and 7 also gave much better results on the coarse grinds than on the fine.

**Discussion**

From the standpoint of composition, the good results obtained on mixtures 3, 5 and 7 can be explained by the use of the "W" plastic clay. All of the other mixtures were bonded with the "K" plastic clay and reference to the curves showing

TABLE VIII

RESULTS OF SPALLING TESTS

| Number | Water dip test (on reheated brick). No. of immersions causing failure. (Average of 3) | Air spalling test. (Brick heated at 1400°C and cooled in air). No. of coolings causing loss of 20% or more. (Average of 2) | Number | Water dip test (on reheated brick). No. of immersions causing failure. (Average of 3) | Air spalling test. (Brick heated at 1400°C and cooled in air). No. of coolings causing loss of 20% or more. (Average of 2) |
|---|---|---|---|---|---|
| 1FS | 2 | 4½ | 6FS | 4 | |
| 1FH | 2 | 1 (Only one brick tested) | 6FH | 3 | 4½ |
| | | | 6CS | 5 | |
| 1CS | 3 | | 6CH | 6 | 17 |
| 1CH | 6 | | 7FS | 3 | |
| 2FS | 5 | | 7FH | 3 | 9½ |
| 2FH | 9 | | 7CS | 8 | |
| 2CS | 10 | | 7CH | 10 | 28 |
| 2CH | 11 | | 8FS | 5 | |
| 3FS | 5 | | 8FH | 3 | |
| 3FH | 6 | 12½ | 8CS | 7 | |
| 3CS | 10 | | 8CH | 8 | |
| 3CH | 9 | 18½ | 9FS | 1 | |
| 4FS | 7 | | 9FH | 1 | 2½ |
| 4FH | 6 | | 9CS | 2 | |
| 4CS | 9 | | 9CH | 5 | |
| 4CH | 12 | | 10S | 5 | 11½ |
| 5FS | 13 | | 10H | 5 | 11 |
| 5FH | 17 | 30½ (one brick broke from being dropped after 26th cooling) | 11S | 8 | |
| | | | 11H | 6 | |
| 5CS | 2 | | | | |
| 5CH | 4 | | | | |

the porosities and firing shrinkages shows the former to be an exceedingly open firing clay with medium shrinkage and the latter to be of the dense firing variety. All of the flint clays used had approximately the same firing characteristics and on this basis it is not possible to make a distinction between the mixtures in which they were varied with the plastic clay remaining constant.

The rapid spalling of mixture 9 appears to be due to the replacement of 10% of the flint clay by a like amount of the dense-firing, calcined plastic clay.

Of the three factors, rate of temperature change, elasticity and coefficient of expansion, which affect spalling, the former apparently has no bearing on the spalling results obtained here, since there is no appreciable difference in this respect between the different mixtures, and this factor will, accordingly, be dropped from the discussion.

The coefficients of expansion and elasticity values, however, do vary considerably, the former to a much greater extent than was anticipated, although not nearly as radically as did the property of elasticity. However, the thermal expansion of mixtures 3, 5 and 7, which gave the best results in the air spalling test, are the highest of any of the mixtures tested, and, while the expansion is directly responsible for the stresses causing failure, its importance must be greatly overshadowed by that of elasticity. Although the elasticity values are somewhat masked by the softening effect and additional data should be obtained to show the relation more clearly, those which are given here are sufficient to prove that this property is the controlling factor in spalling and that it can be varied over wide limits.

Mixtures 1FS and 9FH, which failed rapidly in the spalling test and which had low thermal expansions, also had the smallest elastic deformation, while the 5FH and 7CH mixtures, which withstood the spalling test the best, and had relatively high thermal expansions, had the greatest elasticity, the difference between the good and poor spalling brick in this respect being in the order of 1 to 3 when measured at 725°C.

In general, all of the results of the elasticity tests paralleled those obtained in spalling, the major discrepancy being on mixture 3FH, which deflected the same amount as 9FH at 635°C, and yet gave materially better results in the spalling test. The particular sample which was tested may not have been representative of those which were spalled and for this reason it is unfortunate that there was not time for additional runs. The test being new, presented a number of difficulties which had to be overcome before progress could be made.

A comparison of the results shown for the fine and coarsely ground brick of mixture number 7 is striking. A ratio of 1 to 3 in the spalling test results was obtained and one of about the same order for elasticity. The coarsely ground brick also takes on a permanent set under a much lower stress than does the finely ground one.

This investigation was outlined several months ago and the most of the data accumulated before it was known that very similar work was being done at the Massachusetts Institute of Technology. The results which are given by Norton[1] lead him to the same general conclusion as that reached here, *i. e.*, that the elastic properties were by far the most im-

[1] "A General Theory of Spalling," *Jour. Amer. Ceram. Soc.*, **8** [1], 29–39 (1925).

portant in determining the resistance to spalling. The coefficients of expansion given by him for some of the commercial fire clay brick are materially higher than any obtained in this investigation, but his values were for a maximum temperature of only 500°C, while those given here were for 800 and 1100°C, and it is possible that the particular specimens tested by him had larger coefficients of expansion over the low temperature range due to excess silica present. The values for elasticity which are given by Norton do not show as great differences between the various fire clay samples tested as are shown here, but this may be explained by the fact that his samples would, in all probability, not vary in structure to the extent that the ones in this investigation did.

It is interesting to know that two such similar investigations as these can be conducted at the same time with fair agreement in the results and the same conclusion reached without knowledge by either laboratory of the other's work. It is unfortunate, however, that there should be such duplication of effort. A central clearing house such as has been suggested at different times for the promotion of efficiency in ceramic research would prevent such occurrences as this.

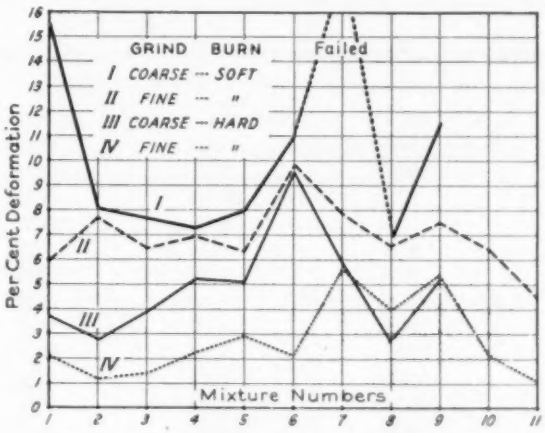


Fig. 15.—Deformation in standard load test. 1350°C—25 pounds/sq. in.

## Deformation under Load

In order to determine the effect of grind and firing upon the deformation of fire clay brick samples of all of the mixtures used in the investigation on spalling were tested under a load of 25 pounds per square inch and at 1350°C, according to the standard method. The results are given in Table IX and shown graphically in Fig. 15.

The average deformation for the finely ground, hard fired brick is 2.76%, for the finely ground, soft fired 6.92%, for the coarsely ground, hard fired 4.97%, and for the coarsely ground, soft fired 9.44%.

From these averages and the detailed figures, it is evident that the degree of firing has a greater influence upon the deformation under load than is usually thought. The influence of grind is noticeable, but the firing produces a much greater effect, in fact it is of even more importance than

the composition of the clays used. The latter statement would certainly not hold true with all clays, but it is only necessary to note the small amount of deformation obtained with the hard fired brick made entirely of plastic clay to realize that the degree of firing is of primary importance.

The differences in results obtained with the various mixtures are not sufficient to allow of any general statements in regard to the effect produced by varying the type of clay. The introduction of calcined flint clay in the place of uncalcined has little or no effect upon the amount of deformation under load, nor does its use reduce the difference between hard and soft fired samples.

TABLE IX

PERCENTAGE DEFORMATION IN THE STANDARD LOAD TEST AT 1350°C AND 25 POUNDS PER SQUARE INCH

| Mixt. | Per cent deformation | Mixt. | Per cent deformation |
|---|---|---|---|
| 1FS | 5.92 | 6FS | 9.86 |
| 1FH | 2.11 | 6FH | 2.13 |
| 1CS | 15.50 | 6CS | 10.90 |
| 1CH | 3.78 | 6CH | 9.66 |
| 2FS | 7.71 | 7FS | 7.86 |
| 2FH | 1.19 | 7FH | 5.63 |
| 2CS | 8.10 | 7CS | Failed |
| 2CH | 2.80 | 7CH | 5.95 |
| 3FS | 6.49 | 8FS | 6.57 |
| 3FH | 1.41 | 8FH | 4.00 |
| 3CS | 7.68 | 8CS | 6.75 |
| 3CH | 3.94 | 8CH | 2.76 |
| 4FS | 6.96 | 9FS | 7.50 |
| 4FH | 2.29 | 9FH | 5.39 |
| 4CS | 7.27 | 9CS | 11.57 |
| 4CH | 5.30 | 9CH | 5.42 |
| 5FS | 6.35 | 10S | 6.47 |
| 5FH | 2.96 | 10H | 2.18 |
| 5CS | 7.98 | 11S | 4.44 |
| 5CH | 5.17 | 11H | 1.11 |

Contrary to our expectations, the deformation of stiff mud brick was greater than that of soft mud products of similar composition. Only two comparisons are possible and the results in those cases are probably peculiar to the particular mixtures used. There was but little difference in grind and porosity between the soft and stiff mud brick which were tested and this partially accounts for the unexpected results.

**Effect of Grind and Firing on Shrinkage**

The figures which are given in Table X, showing the drying and firing shrinkage, were obtained at the plant where the test pieces were made and were supplied by S. M. Kier.

A study of these results reveals some points which should be of considerable interest to the manufacturer. The influence of grind on both

drying and firing shrinkage is especially pronounced and indicates the necessity for accurate control in this part of the manufacturing operation when a product of uniform size is necessary. An average of all of the results gives the following:

| | Shrinkage by volume | | |
|---|---|---|---|
| | Drying | Firing | Total |
| Fine grind | 11.8% | 10.5% | 21.0% |
| Coarse grind | 7.3 | 5.9 | 12.8 |

The linear shrinkages would be approximately one-third of those given and the difference in total shrinkage would amount to almost $^1/_4$-inch on a length of 9 inches.

It may also be noted that in several cases the firing shrinkage of the soft fired brick is greater than that of the hard fired ones. This is largely due to the secondary expansion, which is discussed under the section on reheating, although it is also found here on the coarsely ground brick of the number 1 group, which are made entirely from plastic clay.

TABLE X

PER CENT VOLUME SHRINKAGE

| Number | Drying, wet basis | Firing, dry basis | Total, wet basis | Number | Drying, wet basis | Firing, dry basis | Total, wet basis |
|---|---|---|---|---|---|---|---|
| 1FH | 17.1 | 12.6 | 26.4 | 6FH | 12.8 | 11.2 | 22.6 |
| 1FS | 17.1 | 13.0 | 27.9 | 6FS | 12.8 | 13.1 | 24.3 |
| 1CH | 11.3 | 2.8 | 13.8 | 6CH | 9.3 | 0.8 | 10.0 |
| 1CS | 11.3 | 12.0 | 21.9 | 6CS | 9.3 | 5.3 | 14.1 |
| 2FH | 12.7 | 14.8 | 25.6 | 7FH | 13.3 | 10.0 | 22.0 |
| 2FS | 12.7 | 13.4 | 24.4 | 7FS | 13.3 | 10.7 | 22.6 |
| 2CH | 6.0 | 6.9 | 12.5 | 7CH | 10.5 | 0.2 | 10.7 |
| 2CS | 6.0 | 13.0 | 18.2 | 7CS | 10.5 | 4.8 | 14.8 |
| 3FH | 10.9 | 14.5 | 23.8 | 8FH | 9.8 | 1.5 | 11.2 |
| 3FS | 10.9 | 13.9 | 23 2 | 8FS | 9.8 | 1.2 | 10.9 |
| 3CH | 8.0 | 8.0 | 15.3 | 8CH | 4.5 | 1.5 | 5.8 |
| 3CS | 8.0 | 10.6 | 17.7 | 8CS | 4.5 | 1.1 | 5.6 |
| 4FH | 11.7 | 14.8 | 24.7 | 9FH | 9.4 | 6.7 | 15.5 |
| 4FS | 11.7 | 12.5 | 22.7 | 9FS | 9.4 | 3.5 | 12.6 |
| 4CH | 7.2 | 10.7 | 17.1 | 9CH | 3.7 | 4.0 | 7.7 |
| 4CS | 7.2 | 8.2 | 14.9 | 9CS | 3.7 | 2.2 | 5.9 |
| 5FH | 9.0 | 13.1 | 20.9 | 10H | 6.2 | 8.9 | 14.6 |
| 5FS | 9.0 | 8.6 | 16.8 | 10S | 6.2 | 13.0 | 18.3 |
| 5CH | 5.6 | 8.3 | 13.5 | 11H | 10.9 | 5.4 | 15.8 |
| 5CS | 5.6 | 6.9 | 12.2 | 11S | 10.9 | 11.5 | 21.1 |

**Reheating Test**

The results obtained by reheating the various brick at 1400°C for 5 hours, which are given in Table XI, show the fallacy of using this test as a means of classifying fire clay brick according to quality.

It may be noted that when expansion takes place with both samples,

TABLE XI

LINEAR AND POROSITY CHANGES ON REHEATING AT 1400°C FOR FIVE HOURS

| Number | Linear change | Apparent original porosity | Apparent porosity after reheating | Porosity change |
|---|---|---|---|---|
| 1FS | 1.26 expansion | 15.2 | 15.0 | 0.2 decrease |
| 1FH | 0.42 expansion | 4.8 | 5.0 | 0.2 increase |
| 1CS | 7.00 expansion | 15.6 | 16.2 | 0.6 increase |
| 1CH | 1.39 expansion | 11.3 | 10.8 | 0.5 decrease |
| 2FS | 0.21 contraction | 22.3 | 19.6 | 2.7 decrease |
| 2FH | 0.24 contraction | 19.4 | 20.0 | 0.6 increase |
| 2CS | 2.88 expansion | 23.2 | 24.2 | 1.0 increase |
| 2CH | 0.54 expansion | 21.6 | 19.3 | 2.3 decrease |
| 3FS | 1.14 expansion | 26.5 | 26.3 | 0.2 decrease |
| 3FH | 0.43 expansion | 23.4 | 23.1 | 0.3 decrease |
| 3CS | 2.27 expansion | 26.1 | 28.5 | 2.4 increase |
| 3CH | 0.59 expansion | 24.2 | 25.9 | 1.7 increase |
| 4FS | 0.33 contraction | 27.0 | 20.5 | 6.5 decrease |
| 4FH | 0.19 contraction | 21.5 | 19.4 | 2.1 decrease |
| 4CS | 0.93 expansion | 24.1 | 16.3 | 7.8 decrease |
| 4CH | 0.84 expansion | 19.4 | 16.1 | 3.3 decrease |
| 5FS | 0.69 contraction | 26.5 | 24.5 | 2.0 decrease |
| 5FH | 0.12 expansion | 25.8 | 24.6 | 1.2 decrease |
| 5CS | 2.19 expansion | 25.9 | 21.5 | 4.4 decrease |
| 5CH | 1.37 expansion | 25.7 | .... | .... |
| 6FS | 0.35 expansion | 22.3 | 17.5 | 4.8 decrease |
| 6FH | 0.29 contraction | 15.0 | 13.8 | 1.2 decrease |
| 6CS | 2.48 expansion | 20.0 | .... | .... |
| 6CH | 0.60 expansion | 16.7 | 15.2 | 1.5 decrease |
| 7FS | 0.51 expansion | 25.6 | 19.1 | 6.5 decrease |
| 7FH | 0.40 expansion | 20.0 | 18.4 | 1.6 decrease |
| 7CS | 2.11 expansion | 25.1 | 21.3 | 3.8 decrease |
| 7CH | 0.48 expansion | 20.7 | .... | .... |
| 8FS | 0.17 contraction | 23.4 | 23.2 | 0.2 decrease |
| 8FH | 0.01 expansion | 22.5 | 22.4 | 0.1 decrease |
| 8CS | 1.70 expansion | 17.9 | 19.2 | 1.3 increase |
| 8CH | 0.26 contraction | 17.9 | 17.5 | 0.4 decrease |
| 9FS | 0.52 contraction | 25.7 | 16.3 | 9.4 decrease |
| 9FH | 0 | 18.8 | 14.7 | 4.1 decrease |
| 9CS | 0.57 expansion | 21.4 | 16.2 | 5.2 decrease |
| 9CH | 0.08 expansion | 17.6 | 17.3 | 0.3 decrease |
| 10S | 2.04 expansion | 17.8 | 13.9 | 3.9 decrease |
| 10H | 0.14 expansion | 13.8 | 12.4 | 1.4 decrease |
| 11S | 1.35 contraction | 19.7 | 16.8 | 2.9 decrease |
| 11H | 0.24 contraction | 14.4 | .. | .... |

those which have been soft fired expand very much more than those which have been hard fired. At the time the reheating test was developed as a means of classifying brick, it was not recognized that expansion would take place to a marked degree from any other cause than over-firing with the accompanying softening and formation of a vesicular structure. It has

since been found that with certain clays an expansion takes place with none of the evidences of over-firing and which is a function of the rate of original firing, as well as the temperature. This has been termed secondary expansion by Harvey,[1] who gives an interesting discussion of the subject.

The cause for this increase in volume is not known. It appears to be greater in amount under reducing conditions than under oxidizing and it is possible that it results from the evolution of oxygen by ferric oxide. That it is a function of the rate of heating is shown by the fact that brick may be fired in a slowly heated silica brick kiln and be of normal size, while if placed near the fire pocket in a fire clay brick kiln being fired only to cone 12, they will be very much over size.[2]

There is no definite relation between the linear and apparent porosity changes in the reheating test. In some cases a marked expansion is accompanied by a porosity increase and in others by a decrease. The true porosity would probably always increase with expansion as there does not appear to be a change in the specific gravity of the material.

This peculiarity of expansion without over-firing is found on clays from several districts, although it is much more pronounced on some of the flint clays from Pennsylvania than on clays from other localities.

This phenomena is of importance in determining the size of the brick fired according to the regular practice as is indicated in the section "Effect of Grind and Firing on Shrinkage" (p. 378).

In order to determine the effect of original firing conditions and rate of heating in the reheating test on the secondary expansion, a number of tests were conducted on brick of one brand made from Pennsylvania flint and plastic clays. In the results shown below the brick marked A were originally soft fired, but of normal size, those marked B were hard fired and normal size, and those marked C hard fired but oversize, while those marked D were soft fired and normal size, but from another lot than the A, B and C samples. The firing temperatures for the B and C lots did not vary greatly, the difference being largely in the rate of heating through placing in different positions in the kiln.

In the first reheat the brick were brought up to 1400°C in about 5 hours and held 5 hours; in the second 1400°C was reached in about 20 hours and the kiln held at that temperature for 5 hours; in the third the temperature was advanced to 1100°C in 3 hours and held there 1 hour; then advanced to 1200, 1300 and 1400°C at the rate of 100° in 30 minutes, the temperature being held at each of these points for one hour and 3 bricks drawn out at the end of each soaking period. In the fourth reheat the temperature was brought up to 1100°C in 5 hours and then advanced

[1] "Note on Secondary Expansion of Flint Clays," *Jour. Amer. Ceram. Soc.*, **7**, 455–6 (1924).

[2] From private notes.

at the rate of 10°C per hour to 1400°C, three samples being drawn at each of the temperatures, 1250°C, 1300°C and 1400°C.

The results obtained in these reheats are as follows:

| Samples | First reheat (1400°C in 5 hours) |
|---|---|
| A | 2.42% expansion (Average of 5) |
| B | 0.20% expansion (Average of 5) |
| C | 0.34% expansion (Average of 5) |

| | Second reheat (1400°C in 20 hours) |
|---|---|
| A | 2.48% expansion (Average of 3) |
| B | 0.31% expansion (Average of 3) |
| C | 0.48% expansion (Average of 3) |

| | Third reheat (rapid rate) | | | |
|---|---|---|---|---|
| | 1100°C | 1200°C | 1300°C | 1400°C |
| D | 0.06% con. (Av. of 3) | 0.57% exp. (Av. of 3) | 2.18% exp. (Av. of 3) | 3.47% exp. (Av. of 3) |

| | Fourth reheat (10°C per hour from 1100°C) | | |
|---|---|---|---|
| | 1250°C | 1300°C | 1400°C |
| D | 0.55% exp. (Av. of 3) | 1.08% exp. (Av. of 3) | 1.73% exp. (Av. of 3) |

The first and second tests do not show appreciable differences in the expansions of the various brick. The third and fourth reheats, however, do show that the rate of heating is a governing factor in determining the amount of expansion and also that the expansion is a function of temperature within the limits of the tests. The rate used in the fourth reheat was as low as would be used in the majority of industrial furnaces during the initial heating up period and the expansion noted would take place in these furnaces unless it is lowered by the effect of the load which the brick supported.

## Acknowledgment

The authors wish to give credit to H. F. Robertson, C. G. Denney and W. R. Kerr, all of whom coöperated extensively in obtaining many of the data given.

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# THE DEVELOPMENT OF A CASTING BODY FOR VITRIFIED SANITARY WARE FROM AMERICAN MATERIALS[1]

By Andrew Foltz

ABSTRACT

This body casts in a very satisfactory manner. The time of two hours is entirely satisfactory when one considers that the molds were exceptionally dry. The pieces put through the bisque kiln came out without signs of warping or cracking. The appearance of the fired body was all that one could expect, considering that it was lawned through 60-mesh and was not magneted. With but slight modifications this body can be worked into our plant without any serious inconveniences.

The cost of the raw materials entering into the formula of Body No. 6 is about $3.00 per ton less than that of a similar body in which English clays are used. This is for the Trenton district.

The results of this work are given more to stimulate interest in the use of domestic materials than to give exact body formulas, it being realized that a formula developed for our peculiar conditions will not necessarily fit into another factory. It is to be hoped that other manufacturers will look into the possibilities of using our American clays.

## Introduction

At the Annual Meeting last year we had a discussion on domestic and imported ball clays and kaolins. The result of this discussion left me with the feeling that everything was not quite what it should be with respect to the imported clays and, after mulling the thing over in my mind for a few months, I decided to try to develop a casting body from domestic clays. Other reasons which led to this decision were the facts that I knew that other potters were using some domestic clays in their mix, that one firm had for a number of years been using American clays almost entirely, and finally that I might show some saving in the cost of my raw materials.

**Plan of Work**

Not being a technical man my scheme of investigation will probably not stand very close scrutiny; however, I wanted to get certain information and of course had to get it as any practical potter would. I decided to learn something of the casting characteristics of various clays that I thought worth considering. Of course I could not try them all, but I picked various ones that are more or less typical. I also decided to submit to the same tests some imported clays which were satisfactory for casting and some that were not, thinking that I might find out why these latter clays could not be made to work. With the results of tests on the individual clays as a guide, the plan was to take those that showed up the best and use them in developing a body.

**Materials Used**

The clays used were in most cases obtained from users, while the feldspar and flint were from our own supply. The materials used and the companies selling them follow:

[1] Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, February, 1925. (White Ware Division.)

| | |
|---|---|
| No. 12 English Ball | John S. Wright, Trenton, N. J. |
| Jernigan Ball (Tenn.) | H. C. Spinks Clay Co. |
| Old Mine No. 4 Ball (Ky.) | Ky. Construction & Improvement Co. |
| Whiteways English Ball | Hammil & Gillespie |
| J-P No. 11 Ball (Tenn.) | Johnson-Porter Clay Co. |
| Atlas Ball (Mo.) | R. T. Vanderbilt Co. |
| Hercules Ball (Mo.) | R. T. Vanderbilt Co. |
| Klondyke Kaolin (Ga.) | Edgar Brothers Co. |
| Cherokee Kaolin (Ga.) | R. T. Vanderbilt Co. |
| Lake County Kaolin (Fla.) | Lake County Clay Co. |
| Edgar Plastic Kaolin (Fla.) | Edgar Plastic Kaolin Co. |
| Harris Kaolin (N. C.) | Harris Clay Mining Co. |
| A-1 China | Hammil & Gillespie |
| M. W. M. China | Moore & Munger |
| Peerless Kaolin (S. C.) | R. T. Vanderbilt Co. |
| Feldspar | Eureka Flint and Spar Co. |
| Feldspar | Genessee Feldspar Co. |
| Flint | Eureka Flint and Spar Co. |

**Procedure**

The tests on the individual clays consisted in making up 5000 gram batches according to the following formula:

Clay 50%
Feldspar 25%
Flint 25%
} All weights calculated on dry basis

These mixtures were blunged in regular bucket agitators with a sufficient quantity of water to make a workable slip and alkali solution made according to the following formula was added from time to time until maximum deflocculation was reached. At this point a small quantity of reserve body was added to bring the slip to a point where settling of the flint and feldspar would not occur; the slip was then lawned through a 60-mesh standard screen, the specific gravity determined and the mixture cast in molds as described later.

The alkali solution used was made up so that each 10 cc. of solution contained 0.5 gram of water glass and 0.5 gram of dehydrated soda ash. The water glass had a specific gravity of 1.36.

Viscosity tests were made with a flow type viscosimeter having a $^5/_{32}$-inch orifice.[1]

The test piece used throughout the preliminary casting tests was designed so that it could be cast by what is termed "solid casting," that is, a core was used. The piece was approximately 4 inches square and $3^3/_4$ inches high and the walls were about $^{11}/_{16}$ inch in thickness, the bottom being slightly thinner. The pour holes were all reamed to the same size, *viz.*, $^{15}/_{16}$ inch. All molds were made from the same case. The slip

[1] See *Trans. Amer. Ceram. Soc.*, **17**, 331 (1915).

entered at what would be the bottom of the piece, that is, the pieces were cast upside down.

In order to determine the relative speeds of casting for the various clays a glass probe was introduced through the funnel at various times and the time noted when the $^{15}/_{16}$-inch opening had entirely closed. The molds were then opened and the pieces were taken out, sponged, dried and fired to cone 9.

The data obtained and observations taken on the clay bodies were:

1. Water added in cc.
2. Standard alkali solution added in cc. for maximum deflocculation.
3. Deflocculation curves for all bodies.
4. Viscosity at maximum deflocculation.
5. Specific gravity at time of casting.
6. Time for shut-off.
7. Character of cast.

An attempt was made to cast all of the mixtures at the same specific gravity, but it was soon found that this was impossible due to the nature of the clays used. It was then decided to use as high a specific gravity as could be maintained and still get a slip that would flow from the viscosimeter. This was accomplished by adding the dry body bit by bit to a definite quantity of water in the blunger, noting how the water "took" the mixture and adding more water as seemed necessary to bring about the desired result. In most cases a quantity of the alkali solution was also added with the water used for adjusting. When the body was thoroughly blunged, additional alkali solution was added until the slip would flow 100 cc. from the viscosimeter without cutting off due to thickening. Alkali solution was then added, 20 cc. at a time, the body blunged 15 minutes after each addition and the viscosity tested for each addition. In the case of clays which were sluggish in their reaction to the alkali the blunging was increased to 30 minutes. The viscosity curves shown all start with the alkali addition at which a sustained flow for 100 cc. could be obtained with the viscosimeter used.

The data obtained and the viscosity curves for the various bodies follow. The numerals shown over each curve represent the specific gravity of the slip when cast; the gravity at maximum deflocculation being approximately 0.01 less in each case.

## Discussion of Preliminary Tests

**No. 12 English Ball** This is a dark-colored clay containing a considerable quantity of lignite. The clay reacts very quickly to alkali and has good flowing qualities. In time required for casting this clay stood highest of all the clays studied. The cast piece

was solid and released well from the core even after being in contact with the plaster for 12 hours.

**Jernigan Ball** This is a dark colored Tennessee clay. Contains some lignite. Has good fluidity and reacts quickly to alkali. Of the dark colored ball clays investigated this clay casts the quickest, the time required being 4 hours. The test piece was solid.

**Old Mine No. 4** A dark colored Kentucky clay. Has good flowing qualities and reacts very quickly to alkali. Contains lignite. In speed of casting it comes next to No. 12 English ball. Casts solid.

**Whiteways English Ball** A clay somewhat lighter in color than some on the market. Much more fluid than No. 12 but reacts about the same to alkali. Contains small amount of lignite. Casts good and solid.

**J-P No. 11 Ball** A light colored Tennessee ball clay. Very sluggish in its reaction to alkali. Flowing qualities not very good for a ball clay. Requires an excessive amount of water to work properly. Casts in $2^1/_2$ hours, being the fastest of the true ball clays. Has tendency toward "livering." Requires more alkali than any other ball clay studied. Casts good and solid.

**Atlas Ball Clay** An exceedingly dark colored clay from Missouri. Contains some lignite. Very good flowing qualities and does not require much alkali for deflocculation. Reacts quickly to alkali additions. Casts good and solid in $4^1/_2$ hours.

**Hercules Ball Clay** Another Missouri clay containing considerable lignite. Reacts very quickly to alkali and requires the lowest amount for deflocculation. Flows well even at high specific gravity. Casts good in 8 hours' time.

**Klondyke Kaolin** A washed Georgia clay. Reacts fairly quickly to alkali and has good fluidity for a kaolin. Casts good and solid in 25 minutes.

**Cherokee Kaolin** Another washed Georgia kaolin. Slightly more sluggish in its reaction to alkali than Klondyke. Has a very long flowing range and good flowing qualities although rather slow. Casts solid in 30 minutes.

**Lake County Kaolin** A washed Florida clay. Very sluggish in its reaction toward alkali. Has very pronounced tendency toward "livering" and requires considerable water to make a workable slip. Requires a large amount of alkali for deflocculation and has a short flowing range within the gravity used. Casts good in $2^1/_2$ hours.

**Edgar Plastic Kaolin** Another washed Florida clay. Practically the same in its action as Lake County Clay but casts somewhat faster, taking but 2 hours.

**Harris Kaolin** A washed North Carolina clay. Very coarse-grained and contains some mica. Very sluggish in its action toward alkali and "livers" readily. No viscosity test could be made due to this "livering" tendency and conditions governing the preparation of the slip for casting had to be gaged by more or less rule-of-thumb methods. The slip shut off in 5 minutes and the results of the test were exceedingly poor, the piece being hollow and it cracked in the mold.

**A-1 China** A washed English clay. Reacts quite rapidly to alkali additions. Does not have good flowing qualities. Casts exceedingly well making a solid piece in 5 minutes.

**M. W. M. China** Another washed English clay, very fine grained. Very sluggish in its action toward the addition of alkali. "Livers" very rapidly. Gave no viscosity range within the specific gravity limits covered. Casts slightly hollow in about 12 minutes.

**Peerless Kaolin** A crude South Carolina clay. Reacts about the same as the Georgia kaolins toward alkali. Has good flowing qualities. Casts good and solid in about 15 minutes.

## Discussion of Deflocculation Curves

The curves in Fig. 1 show the point of alkali addition at which the slips would first give a maintained flow of 100 cc. without thickening. They also show the alkali additions necessary for complete deflocculation. It will be noted from the numerals over each curve, which represent the specific gravity at maximum deflocculation, that this characteristic was not constant. If all gravities had been brought to that of the lowest recorded, namely Lake County kaolin at 1.62, the effect would be to lower all curves toward the base line and to increase the distance between the point of maximum deflocculation and the point at which sustained flow began.

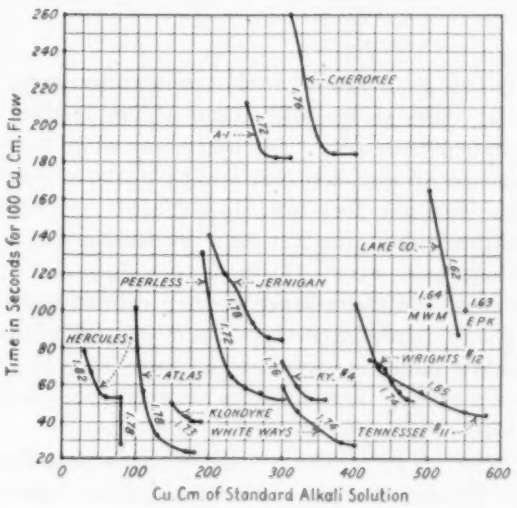


FIG. 1.

This of course would have no effect on the amount of alkali necessary for complete deflocculation.

It will be noted that the clays roughly group themselves into three groups, *viz.*, those requiring less than 200 cc. of alkali solution, those requiring between 200 cc. and 400 cc. of solution, and those requiring over 400 cc. for complete deflocculation. No definite relation can be noted between the amount of alkali required for deflocculation and the action of the clays in casting. Most of the clays, however, that required over 400 cc. for deflocculation were very sluggish in their reaction to the addition of alkali.

## Study of Combinations of Clays

With the results of the tests on the individual clays at hand, two questions at once came up. These were: (1) Will a slow-casting ball clay in combination with a kaolin cast more slowly than a quick-casting ball clay in combination with the same kaolin, and (2) will the amount of alkali necessary for complete deflocculation of two clays in combination be equal to the sum of the percentages of the individual clays times the amount of alkali necessary to deflocculate each clay? For this test Old Mine No. 4 ball clay, Hercules ball clay, and E. P. K. kaolin were used.

The combinations used were as follows:

| | No. 1 body | No. 2 body | Alkali required, cc. | Time for casting, hrs. |
|---|---|---|---|---|
| Old Mine No. 4 | 25 | .. | 360 | 11 |
| Hercules | .. | 25 | 80 | 8 |
| E. P. K. | 25 | 25 | 550 | 2 |
| Feldspar | 25 | 25 | ... | .. |
| Flint | 25 | 25 | ... | .. |
| Body No. 1 | .. | .. | 440 | $2^3/_4$ |
| Body No. 2 | .. | .. | 120 | 4 |

This test shows that the combination of an 8-hour clay with a two-hour clay casts more slowly than a combination of an 11-hour clay and the same 2-hour clay. Furthermore, while body No. 1 would indicate the answer to question No. 2 to be in the affirmative, body No. 2 shows that the relation does not always hold. Another combination of clays put through the same test gave the same result. The conclusions drawn from these tests were: (1) in casting slips, clays in combination lose to some extent the characteristics they exhibit individually and while results of tests on individual clays are of great aid, one cannot use them as an absolute guide in compounding body mixtures, so that (2) the development of a casting body must be studied from the standpoint of combination of clays.

## Study of Casting Bodies

There were three primary conditions that must be met in developing a casting body for our plant: first, it must mature at cone 9; second, it must

be suited for "solid casting;" and third, it must "cast up" in not more than $2^1/_2$ hours. Other considerations which probably apply to all sanitary ware casting are: (1) it must "stick up" readily; (2) it must have good flowing qualities; (3) it must release easily from the cores; (4) it must have a dry strength sufficient to withstand ordinary handling; (5) it must sponge smoothly; (6) it must have a good fired color; and (7) it must not warp during firing, nor dunt. Another quality which, though desirable, is not entirely essential is that the body should show a maximum deflocculation with an alkali addition of not over $^4/_{10}\%$ of a half and half mixture of dehydrated soda ash and water glass having a specific gravity of 1.40.

From the results of the casting tests on the individual clays and from other physical data as noted, it was decided that the following clays would be tried in the body development.

| | |
|---|---|
| Lake County Kaolin | Color, strength |
| Peerless Kaolin | Flowing quality, cost |
| Harris Kaolin | Color, open texture. |
| Old Mine No. 4 Ball | Color, flowing qualities |
| Jernigan Ball | Fast casting |
| Hercules Ball | Color, flowing qualities, low alkali |

Three body mixtures were made as follows in order to study the action of these clays in combination. The batches were 10,000 grams each and the method of preparation and casting was the same as that described for the individual clays.

| | No. 3 | No. 4 | No. 5 |
|---|---|---|---|
| Feldspar | 20 | 23 | 25 |
| Flint | 30 | 32 | 30 |
| Lake County | 10 | 8 | 6 |
| Peerless | 16 | 8 | 8 |
| Hercules | 6 | 6 | 8 |
| Old Mine No. 1 | 18 | 6 | 18 |
| Jernigan | .. | 12 | .. |
| Harris | .. | 5 | 5 |

The results of these tests were:

| | Cc. alk. solution | Min. viscosity | Sp. gr. | Time for shut-off |
|---|---|---|---|---|
| No. 3 body | 370 | 80 sec. | 1.85 | $3^1/_4$ hrs. |
| No. 4 body | 350 | 92 sec. | 1.85 | 2 hrs. |
| No. 5 body | 320 | 93 sec. | 1.84 | $2^3/_4$ hrs. |

With the results of the tests on the above mixtures as a guide, it was decided to make up the next body on a semi-factory scale and cast a large tank and cover. We have a miniature slip house equipment in our laboratory and we have used this enough to know that when results are satis-

factory from this equipment, only slight adjustments are necessary to put a body directly in the factory. The machine handles 100 lbs. of dry material per batch.

The batch for the semi-factory test was:

BODY NO. 6

| | |
|---|---|
| Genessee Feldspar | 35 |
| Eureka Flint | 25 |
| Lake Co. Kaolin | 5 |
| Peerless Kaolin | 7 |
| Harris Kaolin | 5 |
| Hercules Ball | 6 |
| Old Mine No. 4 | 17 |

This body tested out as follows:

| | |
|---|---|
| Alkali solution used | 1700 cc. |
| Alkali solution necessary for complete deflocculation | 1800 cc. |
| Specific gravity when cast (30²/₃ oz. per pt.) | 1.84 |
| Time for 100 cc. flow at sp. gr. of 1.84 and 1700 cc. alkali addition | 86 sec. |
| Time required to cast | 2 hrs. |

| Clay | $H_2O$ added in cc. | Cc. of standard alkali solution | Viscosity | Wt. per 100 cc. | Character of cast | Time for shut-off |
|---|---|---|---|---|---|---|
| English No. 12 | 1950 | 480 | 52″ | 174 | good | 12 hrs. |
| Jernigan Tenn. | 1900 | 300 | 83″ | 178 | good | 4 hrs. |
| Kentucky No. 4 | 2000 | 360 | 51″ | 176 | good | 11 hrs. |
| Eng. Whiteways | 1900 | 400 | 28″ | 174 | good | 10 hrs. |
| Tenn. No. 11—J.P. | 2750 | 580 | 43″ | 165 | good | 2½ hrs. |
| Atlas | 2100 | 180 | 24″ | 178 | good | 4½ hrs. |
| Hercules | 2150 | 80 | 28″ | 178 | good | 8 hrs. |
| Klondyke | 2300 | 190 | 42″ | 173 | good | 25 min. |
| Cherokee | 1900 | 400 | 194″ | 176 | good | 30 min. |
| Lake | 2950 | 540 | 87″ | 162 | good | 2½ hrs. |
| E. P. K. | 3400 | 550 | 100″ | 163 | | 2 hrs. |
| Harris | 2680 | 335 | ... | 167 | hollow n. g. cracked | 5 min. |
| A1 | 2300 | 260 | 237″ | 172 | good | 5 min. |
| M. W. M. | 2750 | 520 | 128″ | 164 | fair | 12 min. |
| Peerless | 2250 | 310 | 51″ | 172 | good | 15 min. |
| Body No. 1 | 2120 | 440 | 123″ | 181 | good | 2¾ hrs. |
| Body No. 2 | 2080 | 120 | 93″ | 185 | good | 4 hrs. |
| Body No. 3 | .... | 370 | 80″ | 185 | | 3¼ hrs. |
| Body No. 4 | .... | 350 | 92″ | 185 | | 2 hrs. |
| Body No. 5 | .... | 320 | 93″ | 184 | | 2¾ hrs. |
| Body No. 6 | | 1700 | 86″ | 184 | | |

LAMBERTVILLE, N. J.

# RAPID CHECK-TESTING FOR FELDSPAR FOR USE IN VITRIFIED FLOOR TILE[1]

By Nugent A. Ragland

ABSTRACT

A simple laboratory test is described wherein successive shipments of feldspar are checked against preceding shipments. This method gives a very accurate idea of variation of feldspar shipments. It outlines a method whereby corrections for relative fluxing values may be made and at the same time body control can be maintained direct from the shop laboratory insuring consistent firing practice from month to month.

Many tests for feldspar have been submitted for approval which include fusion buttons, cones, flow trials, chemical analyses, etc. Chemical analyses have been more or less popular but due to the fact that the average layman does not reckon his feldspar in terms of "ideal feldspar," we have submitted a test now carried out at the Perth Amboy Tile Works which has given us satisfaction and has been adopted as standard practice for body control. It also gives us an idea of the "fluxing value" of successive cars of feldspar checked against a standard.

All tests are carried out on the dry basis, percentage being taken as such. Therefore, it is necessary to determine the batch weights of the standard body upon the dry weights.

When a car of feldspar arrives, it is sampled by collecting approximately fifty pounds from various parts of the car. This is piled and quartered rejecting opposite quarters, and the same process repeated a second time.

The remainder is placed in a laboratory oven and thoroughly dried over a hot plate or in a drier at 212°F.

The following procedure is followed using at all times moisture-free ingredients. The standard body is composed of 60% feldspar, 5% flint, and 35% clay. At the above figure the feldspar is assumed correct for the present firing temperature. When a shipment of feldspar arrives it is sampled, and the following bodies are made up holding the clay content constant at 35%. The difference of feldspar is made up with flint.

| Body | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 |
|---|---|---|---|---|---|
| Feldspar | 56 | 58 | 60 | 62 | 64 |
| Flint | 9 | 7 | 5 | 3 | 1 |
| Clay | 35 | 35 | 35 | 35 | 35 |

This procedure is carried out because the impurity in feldspar is usually flint and occasionally a small amount of clay which is negligible.

The trials of these bodies are pressed and also the trials of the standard body or commercial body then in use. Some trials are set out for check against the following car. It is necessary that the moisture content of the

[1] Recd. Jan. 27, 1925. Presented at the Annual Meeting of the American Ceramic Society, Columbus, Ohio, Feb., 1925. (White Ware Division.)

dust is constant in each body and that the pressure applied to the trials is the same in all cases. These trials are fired with like body trials face to face in the extreme and easy part of the kiln, *viz.*, one sagger directly over the bag wall and one sagger in the center at the floor of the kiln. The bodies should be set together carefully packed in sand, and cone pats should be placed in each sagger.

The fired trials are compared for shrinkage and the ink test is used upon each trial. Use the new shipment of feldspar between the limits of where it takes ink in the fourth ring and where it sticks to the other trials (or blisters) in the first ring keeping toward the limit of the ink test in the fourth ring. Of course, firing must be even and constant in all cases.

When the next shipment arrives it is made up and checked in the same manner against the former shipment using the ink test and observing blistering and sticking limits.

If the shrinkage of the proper body is too high or too low, it may be overcome by addition or subtraction of clay at the expense of flint.

In commercial practice we fire a good cone 11 down and attempt to soak this cone down in all parts of the kiln. Naturally the desirable feldspar for our use, then, is one which shows a fairly low vitrification and a high overfiring temperature.

This method, while very simple, gives us:

(1) Uniformity of firing conditions (or temperature) from kiln to kiln, eliminating guess work and hazard and enables the fireman to fire successive kilns alike thereby acquiring better efficiency.

(2) Idea of fluxing values of successive shipments of feldspar.

(3) Complete body control from laboratory, any errors occurring being mechanical or firing defects.

Perth Amboy Tile Works
Perth Amboy, N. J.

# POTS AND PINES, A DECORATIVE PROBLEM FOR THE ARTIST POTTER[1]

By Margaret K. Cable

ABSTRACT

A descriptive article outlining the method of producing a soft green pine tree decoration for vases and pots.

## Introduction

My vacations are spent among the pines of northern Minnesota. I drink them in all summer, I long for them all winter, and being a potter they naturally have formed the "theme" of many a pot.

It is my purpose to outline here the method followed in the production of the soft green pine tree vase shown in the accompanying photograph. This type of decoration and this particular spruce-green color effect has been reproduced many times by my advanced students in ceramics, which fact together with the photograph should prove that the process is a practical one.

Fig. 1.

**Body** A light-colored cream or buff body is essential if the semi-transparent matt glaze given below is employed. Entirely different color effects would be produced were a red or dark firing clay used.

**Shaping the Ware** The pieces may be hand-built, thrown or cast, at the convenience of the worker, but a smooth even finish upon which to paint the pattern is needed. The form and size should be suited to the pine tree design.

**Drawing in the Design** After the wet clay piece has been fashioned and finished down quite smooth, allow it to dry out completely to the dry "green" stage. The form is now ready to decorate. The pine tree pattern may be traced or drawn free hand on the dry clay pot with a pencil or brush.

**Painting in the Color** Place about a gram of copper carbonate on a ground glass slab and add two or three drops of dissolved gum arabic and enough water to make a thin paste. Grind with a palette knife until thoroughly mixed and perfectly smooth. Thin out with water to a consistency which will flow easily from the brush. Select

[1] Presented at the Annual Meeting, American Ceramic Society, February, 1925. (Art Division.)

a large soft water-color brush and apply the color to the pattern in a very thin even coat. Care must be taken to get the copper wash very thin and as even as possible for, if put on too heavy or lumpy, the copper will develop in the kiln uneven dark and metallic spots in the glaze. The decorated ware should then be biscuited to cone 05 or 06.

**The Glaze**

The biscuit piece is then glazed with a thin coating of one of the glazes given in the table below, depending upon the color desired. If a dark green pine tree is to blend into a lighter green background the green glaze should be used. Or a green and blue color combination may be achieved by using the blue glaze, in which case the pine trees will show up green against the blue background.

If, however, a brown glaze is to be applied the pattern painted in copper will come through in a darker shade of brown. Some very pleasing effects are obtained by painting a design of bare trees upon the pot, the interlacing branches of which form a semi-conventional border about the top, while the upright trunks serve as a pleasing perpendicular breaking of the background space. A brown glaze shading off into a tan yellow applied over this pattern gives the effect of naked trees against a soft hazy sunset sky.

CHEMICAL FORMULA OF GLAZE

$$\left.\begin{matrix} PbO & 0.476 \\ CaO & .430 \\ K_2O & .094 \end{matrix}\right\} \left\{ Al_2O_3\ 0.378 \right\} \left\{ SiO_2\ 1.13 \right.$$

**Batch Weights**

Grind in a ball mill for 1½ hours. Screen through 100-mesh screen. Add 1 teaspoon dissolved gum arabic before screening.

| | Green | Blue | Brown | Yellow |
|---|---|---|---|---|
| White lead | 200 | 200 | 200 | 200 |
| Whiting | 70 | 70 | 70 | 70 |
| Feldspar | 85 | 85 | 85 | 85 |
| Kaolin | 120 | 120 | 120 | 120 |
| Black oxide copper | 7 | | | |
| Black oxide iron | 3 | | | |
| Black oxide manganese | 1.5 | | | |
| | 486.5 | | | |
| Black oxide cobalt | | 1.5 | | |
| Black oxide nickel | | 1 | | |
| | | 476.5 | | |
| Black oxide manganese | | | 6 | |
| Black oxide iron | | | 13 | |
| | | | 494 | |
| Black oxide managese | | | | 3 |
| Black oxide iron | | | | 6.5 |
| | | | | 484.5 |

**Application of Glaze** The above body glaze is of the stationary type, that is, it remains exactly where it is put provided it is not put on too heavy or much overfired. When applied in a medium thin coat and fired at the temperature indicated, it comes from the kiln a soft, silky, semi-transparent matt.

This glaze does not, however, correct any defects of application and must, therefore, be applied with great care. The ideal method, when dealing with a glaze of this kind, is to spray it on with compressed air, but if this is not available it can be either poured over the pot or the piece dipped in a bath of glaze. In either case the finger marks must be retouched very carefully and all drips or uneven places scraped down to prevent their showing in the finished work.

**The Fire** The glazed pots should be handled as little as possible and placed in the kiln with care as the scratch of a finger nail or the least chipping or marring of the unfired glaze will disfigure the fired ware. Firing should be carried to cone 1 in an ordinary oil-burning muffle kiln of the usual type.

**Caution** To be on the safe side, it is better to have the copper wash a little thin rather than a bit too thick.

The same may be said with reference to the application of the glaze. It will not turn bright or glossy if applied thin, as many other matt glazes have an unpleasant habit of doing. Therefore, put it on evenly but not too generously. Remember that a thinly glazed piece can, if necessary, be reglazed and refired, but a pot with a thick heavy coat of glaze, which obliterates the decoration beneath, is a lost pot and like the luckless pot of Omar, which was marred in the making, may find itself consigned to a warmer place than the kiln, which would be a sad end for a cool breezy pine tree pot.

University of North Dakota
Grand Forks

# KILN STOKERS[1]

By John D. Martin

ABSTRACT

This paper presents the industrial application of kiln stokers, a description of which has been previously given.

During the last year we have been operating a kiln firing refractories equipped with these stokers. It is a round down-draft kiln and we have fired it about once every six weeks. During this time we have been running what might be called a continuous test of the stokers from a mechanical standpoint to develop and correct such weaknesses which would become evident from wear, breakage, warpage and burning out of some of the parts.

An experience of twenty-five years with machinery has shown me that because a machine when new will start working quite well, it does not always follow that it can be considered a finished product. Although the theory of the machine may be well founded, its performance may eventually be unsatisfactory on account of faulty design, the poor choice of materials of construction resulting in excessive wear or breakage or both.

As to the general theory of our stoker the rotating round grate which we employ was first used in England over one hundred years ago, while an auger feed and the underfeed principle which we use are both very old in the art of combustion. However, certain of our claims of improvements over past forms of such stokers have been allowed by the United States Patent Office.

I do not contend that some sort of properly designed overfeed or chain grate stoker cannot secure results in firing clayware, but this will be a much more complicated machine than ours when worked out to use forced draft, which should be utilized by all means. One of our chief aims has been to avoid a complicated machine that a fireman of average intelligence could neither understand nor operate.

Our stoker consists of a horizontal feed pipe placed below the grate level and this extends from a coal hopper on the outside of the kiln to a point underneath the center of a round grate where it is attached to the specially constructed feed pipe ell. Extending upward from this ell is a vertical feed pipe which conveys the coal upward toward the center of the grate by means of a vertical auger in the same manner as the coal is conveyed from the outside hopper to the ell by the horizontal auger operating in the horizontal feed pipe. Power is applied to turn the horizontal auger at its outer end of course, and also to drive a shaft which extends back

[1] Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, Feb., 1925. (Heavy Clay Products Division.) Other presentations of the subject by Mr. Martin have been published. See *Jour. Amer. Ceram. Soc.*, **6** [10], 1044 (1923); *ibid.*, **7** [12], 887–888 (1924).

underneath the horizontal feed pipe into the bottom compartment of the ell where by means of a pair of miter gears we impart rotation to the vertical auger. This is done by means of a short vertical shaft which extends upward from one of these miter gears into a square hole in the central core of this auger.

The frame which supports the grate has a central sleeve which fits over the vertical feed pipe and rests on the top of the ell which acts as the bearing. The frame is thus supported by the top of the ell and the vertical feed pipe and is free to rotate. The ell itself is held in place by a large ring set in the brickwork of the kiln having spokes extending inward toward the ell. They end in another ring which encircles the ell and supports it.

The sleeve spoken of above which fits over the vertical pipe has spokes extending outward and these carry the grate at their outer ends. The outside edge of the grate lies over the edge of the large ring set in the brickwork, and this grate as a whole is approximately cone shaped. It is composed of a series of flat rings placed one over the other and each one is smaller in diameter than the one below. Combustion air enters the fuel bed in a horizontal direction between these rings. They are made wide enough so that the siftings cannot normally fall off their inside edge into the windbox which of course is the compartment immediately underneath the grate.

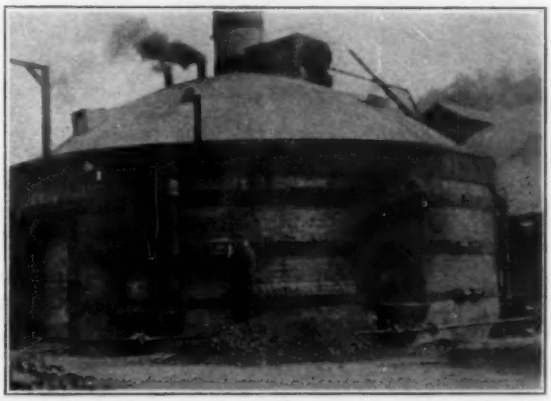

FIG. 1.—Refractories kiln, stoker fired.

Coal entering on the grate through its center at the top of the cone gradually works its way down over the grate to its outside edge where it can be scraped off as ash as the grate revolves. This ash falls outside of the windbox into the bottom of the passageway in the kiln wall made as part of the stoker layout. The bag wall of the furnace will be a half circle set around the inside half of the grate. The other half of the grate should be under the kiln wall arch.

The stokers are all driven from one point by means of shafting equipped with universal joints to enable it to go around the kiln from one stoker to another. This shafting is on a level with the center of the horizontal feed pipe and would generally be about a foot off the ground.

Forced draft is introduced from one side of the windbox just underneath the outside edge of the grate. It cannot be interfered with by any accumulation of siftings under the grate because a way is provided to automatically discharge them by means of the rotation of the grate together with a small spiral wrapped around the horizontal miter gear shaft from the ell to the outside of the wind box. Thus this shaft also acts as a conveyor to discharge siftings from the windbox.

One of the most troublesome things for us to solve has been to find the best means to rotate the grate. We started by using shafts and gears but the expansion and slight warpage of these parts under heat resulted in so much trouble we gave these up. But this experience taught us always thereafter to see the necessity of providing ways and means of handling expansion and warpage which cannot be avoided in such a way as to keep us out of trouble. We next put a chain sprocket around the bottom of the central grate frame sleeve and for about two years rotated the grate with a chain and during this period we increased the size of the chain three times. The shaft of the driving sprocket is driven by a pair of worm gears, the worm being located on the horizontal miter gear shaft underneath the horizontal feed pipe. We have recently found, however, that we can simplify the construction by the use of a ratchet drive having fewer and less expensive parts. A recent test has shown very gratifying results. We fired this stoker for a week with the kiln empty but we closed in the bag wall on top to make the furnace very hot. During this time the stoker developed no mechanical trouble whatever. We finally decided to see if we could not stall the grate so the hot bag wall was deliberately tipped over and allowed to fall onto the grate. But apparently even more drastic means than this would have to be employed as this neither stalled the grate nor injured it. It carried this load and kept on revolving just the same.

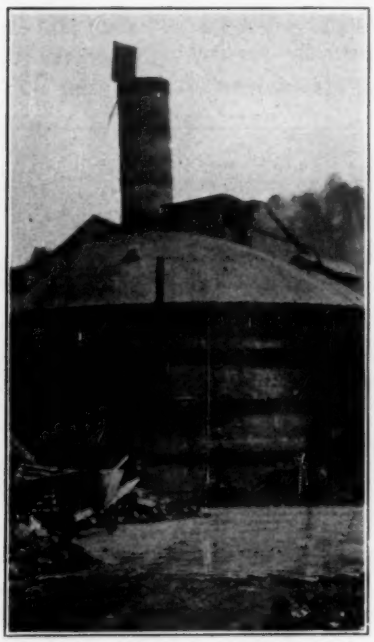

FIG. 2.—Kiln on high fire, notice absence of smoke.

Our experience with the means of rotating the grate is typical of the development of most of the stoker. Our aim has not been to let any part

of the stoker get by in just a fashion but to find and use the best means we can evolve. One of these stokers in operation seems to be quite a simple affair but it has been no simple matter to develop it so because literally every square inch of it has been gone over time and again to fit it to stand the heat strains of expansion and contraction, the crowding of the furnace walls against it, the very great difficulty of furnishing any proper lubrication to some of the parts and to protect it against the presence of tramp iron in the coal. We have tried many ideas which were dismal failures, but so far we have not met a problem which we have not eventually been able to solve; but a detailed story of all the different devices and schemes which have been tried out and most all of which have been discarded, in order at first to make the stoker work at all, and finally to simplify it and make it perform better and better, would fill a volume as we have now spent over four years and thousands of dollars on the problem.

FIG. 3.—Stoker in position showing shaft drive.

Some of our difficulties have not shown up with certain features until they have been in operation for as long as a year. About four months ago, for instance, the vertical augers in one after the other of the stokers commenced to run very hard and some of them stuck and would not move at all. We found the trouble was in the lower compartment of the feed pipe ell where the miter gears are located. The miter gear on the short vertical shaft which operates the vertical auger had been placed so that its teeth were on top. This shaft has a bearing where it goes through the wall which separates the lower and upper compartments of the ell. After this bearing wears, fine coal dust will come down through it and fill the lower compartment sufficiently to clog the teeth of the miter gears and prevent them from operating. We first tried stopping this condition by using a bushing for a bearing through this wall. The bushing was screwed into the wall and extended upward into the central core of the vertical auger. We thought no fine coal dust would find its way upward over the

top of this bushing and thence down into the lower compartment. After the dust rose about two inches along the outside of this bushing, there being a clearance between it and the auger of $^1/_{16}$ inch, and before it reached the top of the bushing, it became so packed that it froze the auger tight and we gave up that plan. We have now installed a hard brass bushing which can be quickly renewed after it wears enough to let dust through and have inverted the miter gear to the top of the compartment to keep it out of any dust for a much longer period and have also provided a way of quickly cleaning out this compartment while the stoker is in operation.

If the fuel bed is kept thin so that it will tail out at the edge of the grate, there will be no trouble with clinker formation on the furnace walls. Of course if a coal is used which has a very high fusion point of the ash there will be no clinker on the wall even if the fuel bed is thick enough to extend upward on it. This has been our experience with a certain grade of W. Va. coal which has a fusion temperature of the ash of 2800°. We have experimented with an air cooled furnace zone extending upward about six inches above the level of the edge of the grate. This zone was made of hollow refractory blocks with air circulated through them, and it did the work. In this connection it may be interesting to note that we had no trouble at all in freezing one of the biggest clinkers we ever saw onto a lining made up of a well-advertised "clinkerless" material composed largely of carborundum and these nine-inch brick cost us something over a dollar each. Fortunately, however, we had only indulged in about thirty of them for a trial.

The fact that we have already spent four years on this stoker will no doubt raise the question in the minds of some as to the probability of our working on a problem which we cannot solve, but it must be understood that the process of testing out any device in actual service which requires many changes, is of necessity a long drawn out one if the testing has to be carried on intermittently as on a periodical kiln which can be fired only once in three weeks. Further delay is also experienced by the time required to make drawings of changes contemplated, having new patterns made for castings, machining and installing them. No doubt we would seem to have progressed faster if we had confined our work to one test stoker, but we have believed that the better way would be to put these stokers to work right under actual firing conditions which we are sure could not be duplicated in any test installation. They are being raised on a diet of hard knocks received in actual service firing clayware, and when they have grown up properly, we will put about four hundred of them to working for us at our plants and will offer them to our industry as a proven means to secure economical firing.

Straitsville Impervious Brick Co.
New Straitsville, Ohio

# CERAMIC ABSTRACTS

Compiled by the

## AMERICAN CERAMIC SOCIETY

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[1] The abbreviation *(C. A.)* at the end of an abstract indicates that the abstract was secured from *Chemical Abstracts* by coöperative agreement.

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## Abrasives

**Method of grain classification.** ANON. *Abras. Ind.*, **6** [3], 90(1925).—A method is described of classifying abrasive grains into various fine sizes for glass polishing. The method is covered by U. S. patent No. 1,519,250. C. J. H.

## Art

**Greek pottery.** F. LAMBERT. *The Pottery Gazette and Glass Trade Review*, **50** [573], 425–6(1925).—This is a report of a lecture given by Mr. Lambert at a meeting of the Art Section of the CERAMIC SOCIETY. P. D. H.

BOOK

**Polychromy.** LEON V. SOLON. With introduction by RALPH ADAMS CRAM, New York. *The Architectural Record* (1924). Price $6.00. H. H. S.

## Cement

**Silicate of soda and concrete. Valuable hardening properties of "P. 84 Silicate."** ANON. *Chem. Age*, **12** [291], 33(1925).—The silicate which contains a higher percentage of silica than water glass is applied to the dried surface or existing concrete. The treated surface becomes hard and wear resistant. What is thought to happen when concrete is treated this way is that there is the formation of free silica in a hard colloidal form in the pores of the concrete. E. J. T.

**Progress of the lime industry in 1924.** U. V. S. KNIBBS. *Chem. Age*, **11** [289], 651(1924).—A brief survey of the general condition of the industry with notes on plants and processes. E. J. T.

**The constitution of basic slag.** T. P. COLCLOUGH. *Chem. Age*, **11** [273], 18–9 (1924).—A basic slag in the fur. may be regarded as essentially a mixt. of tetra-calcic phosphate and monosilicate of lime contg. in soln. greater or smaller amts. of oxides of Fe, Mn, with Al. MgO and in special cases fluorspar, the function of the latter being purely a phys. one, to give greater fluidity to a slag of the required lime content. E. J. T.

**Reviving "dead" modifications of calcium sulphate.** P. P. BUDNIKOFF AND M. E. LEWIN. *Ber. Polyt. Iwanwo-Wosniessensk*, **8**, 32–9(1924); *J. Soc. Chem. Ind.*, **44B**, 172–3(1925).—Anhydrite or dead-burned plaster can be revivified by addition of suitable reagents like NaOH, $Na_2HPO_4$, $NaHSO_4$, CaO, $MgSO_4$, $MgCl_2$, $ZnCl_2$, and $Al_2(SO_4)_3$. As the gypsum crystallizes, the catalyst separates at the surface. A cement produced by addition of 1% $NaHSO_4.H_2O$ gave strength tests of 29.5 kg. per sq. cm. after 3 days, 32.8 after 7 days, and 49.1 after 28 days. H. H. S.

**Building materials in 1924.** W. J. REES. *Ann. Rept. Soc. Chem. Ind.*, **9**, 297–303 (1924).—A noteworthy event of the year was the Internat. Cement Congress held in London in April. (1) A number of papers on *ciment fondu* indicates the interest in

this quick-hardening cement. Port. cement mfrs. have responded with a true Port. cement that gives tests higher in 24 hrs. than are demanded by the Stand. Specif. at 28 days. Ferrocrete, one of these new brands, carried a load of 6 tons on a 6 x 10 inch concrete beam of 15 ft. span at an age of 2 days, and a load of 10 tons at 7 days. (2) KUHL, and GUTTMANN and BIEHL, have investigated the action of fluorspar in a cement mix. Cements which, when rapidly fired, will not stand the boiling test, showed no cracking when 5% fluorspar was added. Addition of fluorspar has no effect on strength at 28 days. Addition of fluorspar 5–10% reduces the temp. required to form cement clinker from 1270° to 1100°. G. and B. say that 3% is the max. for safety, an excess causing the clinker to disintegrate. Calcium sulphate, according to K., is a good mat. to grind with slags. The best strengths were given by a mixt. of 86 slag, 8 lime, 3–9 $CaSO_4$, and a mixt. of 70 slag, 30 clinker, 2–10 $CaSO_4$. (3) Pamphlet No. 3 of the Brit. Port. Cem. Research Assoc. deals with the exothermic reactions in clinker formation. It is computed that the heat evolved during clinker formation is about 40 million B.t.u. per 100 tons of clinker. TROCHE has discussed the use of calcium chloride in protecting cement and concrete from frost. Mortars composed of equal vols. of cement and sand with 10–15% anhyd. $CaCl_2$ do not freeze at $-5°$ to $-10°$, and setting does not commence until an hour after mixing. (4) The addition of silicate of soda to concrete when gaging is recommended by MUNRO, particularly with ref. to its use for roads and factory floors. The concrete is rendered very resistant to abrasion, and the tensile and crushing strengths are not reduced. H. H. S.

**What is alite? Newer investigations regarding constitution of the Portland cement clinker.** WALTER DYCKERHOFF. *Zement*, **13**, 455–7, 467–72(1924).—The author claims that the $\alpha$-bicalcium silicate is the carrier of the alite in the Port. cement clinker. W. S.

**High valued cement and strength of concrete.** DAHLKE. *Zement*, **13**, 481–2 (1924).—Comparing pressure tests on shaft kiln cement of the mixtures 1:3, $1^1/_4$:3, $1^1/_2$:3, 2:3, first with stand. sand and then with wall sand plus gravel. W. S.

**Destructions of concrete and ferro-concrete buildings in gas and water works. Causes and protection.** E. PROBST. *Gas und Wasserfach.*, **67**, 513–5(1924).—The destructions are caused mostly by attacks of soda water or fluids contg. sol. sulphates on the Ca contents of the cement. W. S.

**Contribution for finding the values of lime in manufacturing of silica brick.** H. SCHILLING. *Chem. Ztg.*, **48**, 787(1924).—In the lime employed the CaO content is to be determined because 2% CaO figured for the fired brick are necessary. Long storage of the lime is to be avoided. W. S.

**Storage of Portland cement which diminishes the quality. Grinding the clinker at the place of construction.** ADOLF SPENGEL. *Tonind.-Ztg.*, **48**, 1157–8(1924).—Cement stored in dry bags loses 60% of its original strength during two years. Clinker can be shipped cheaper than cement, and it is sometimes more economical to grind the clinker where it is used; *e. g.* canal constructions. W. S.

## Enamel

**Use of metal, enameled, and porcelain vessels in manufacturing pharmaceutical preparations.** D. H. WEBSTER. *Arch. Pharm.*, **262**, 575–7(1924); *J. Soc. Chem. Ind.*, **44B**, 189(1925).—Plates of various mats. were boiled with four pharmaceutical liquors and with normal NaOH and $H_2SO_4$. Porcelain was the best, and enameled metal the worst, resistant mat. Intermediate in order were: Krupp's Nirostastahl $V_2A$; German-silver; copper, brass, tombak and phosphor-bronze, these four being approx. equally liable to attack; aluminum; and tin. H. H. S.

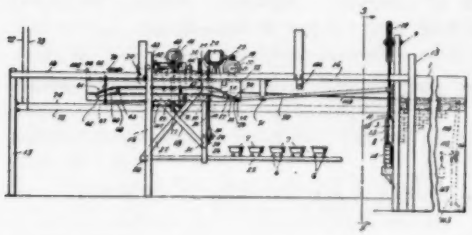
**The protection of iron at red heats with a metal coating.** G. KUTSCHER. *Keram. Rundschau*, **33**, 55–6(1925).—The destruction of iron at red heats is considerable due to the oxidation of the same. Molten Al is sprayed on the same after it has been sandblasted and the aluminum unites with the Fe. In the subsequent firing the Al is oxidized to $Al_2O_3$ which is very refrac. and thus the Fe is protected with a coating of refrac. $Al_2O_3$. The spraying of grate bars with Al in this manner has greatly prolonged the life of these. Metal spraying is used for many other purposes. It is claimed that a metal spray may be put on combustible mats. as paper, wood, and cloth as well as on metal, stone, unglazed porcelain, plaster, etc. The metal to be sprayed on other mats. is fed into the spray gun as a wire. The wire is melted and sprayed by means of gas and compressed air of 2.2 atmos. The capacity of one of these spray guns varies with the fusibility of the metal to be sprayed varying from 6 kg. for easy melting metals to 0.8 kg. for metals which melt with difficulty. A thickness of $^1/_{20}$–$^1/_{20}$ mm. is usually sprayed on grate bars while ware coated to make it resistant to chems. is now being coated with a thickness of $^2/_{10}$–$^5/_{10}$ mm. It is very important that the metal surface to be sprayed be rough and freshly sand blasted as the metal will not stick as easily to smooth surfaces which have not been sandblasted. The use of acids to clean the surface is not necessary. H. G. S.

**The behavior of metal oxides in ground coats on sheet metal.** L. VIELHABER. *Keram. Rundschau*, **33**, 53–5(1925). H. G. S.

**The importance of fluorine compounds in enamels.** W. ESCH AND F. SCHULTZ. *Chem. Ztg.*, **48**, 901(1924).—The history of the use of $Na_2SiF_6$ is reviewed. (*C. A.*)

PATENTS

**Charging fork for enameling furnaces.** FRANCIS M. KOCH. U. S. 1,534,649, April 21, 1925. A charging fork for furs. including means for moving the fork into the fur., coöperating mechanism set in opern. by said inward movement of the fork for automatically moving the fork vertically within the fur., and coöperating mechanism set in opern. by said vertical movement of the fork for automatically withdrawing the fork from the fur.



**Glass and enamel.** GENERAL ELECTRIC CO., LTD. Brit. 223,837, June 24, 1923. Glasses or enamels of low m. p. are formed of the following compn. (by mol. proportions): PbO 1, $B_2O_3$ 0.45–0.55, $SiO_2$ 0–0.20, $Al_2O_3$ 0.04–0.20, $Na_2O$ 0.04–0.07, $K_2O$ 0.01–0.02, $As_2O_3$ 0–0.01 and $Co_2O_3$ 0–0.04. The $Co_2O_3$ may be replaced by other coloring or opacifying agents. These compns. melt generally at 360–400° and are suitable for marking elec. lamp bulbs and for use as an adhesive between metal, glass, porcelain and other materials or for coating glass or metal articles. (*C. A.*)

**Enameling ceramic wares.** V. M. GOLDSCHMIDT. Norw. 40,171, Nov. 3, 1924. After it is fired for the first time the article is moistened with an aq. soln. of a boron compd. and fired again. (*C A.*)

## Glass

**The influence of barium carbonate in glass.** ANON. *Keram. Rundschau*, **33**, 192(1925).—$BaCO_3$ because of its strong fluxing action and cheapness is continually being substituted for PbO in the glass industry. Like PbO this oxide produces a glass with a high index of refraction and only costs about $^1/_5$ as much. H. G. S.

**The fuel consumption in different glass furnaces.** H. BARTH. *Keram. Rundschau*, **33**, 191(1925). H. G. S.

**Strass glass.** R. SCHMIDT. *Keram. Rundschau,* **33,** 51–3(1925).—Strass glass is that type of glass which is used as the base for artificial gems. The early types of this glass had a compn. as follows: $SiO_2$ 46%, $K_2O$ 9%, and PbO 55%. The more recent strass glasses contain less PbO and considerable $B_2O_3$. The compn. of such a glass is as follows: $SiO_2$ 55%, $B_2O_3$ 11%, $Na_2O$ 5%, $K_2O$ 13%, and PbO 16%. This glass has a lower index of refraction than the high PbO glass but is more brilliant due to the $B_2O_3$. It however is a little too soft so a third strass glass has been developed which is made harder by substituting CaO for some of the PbO. A glass of this compn. is as follows: $SiO_2$ 51.3%, $B_2O_3$ 5.0%, $Na_2O$ 2.2%, $K_2O$ 12.3%, CaO 4.4%, and PbO 24.8%. The compns. of many other strass glasses are given in this article. H. G. S.

**Sorption of ammonia and carbon dioxide by glass. Time and pressure relationships.** D. H. BANGHAM AND F. P. BURT. *Jour. Phys. Chem.,* **29** [2], 113–29(1925).—The rate of sorption of ammonia by a glass surface at 0°C was measured at a number of different and approximately const. press. The relationships $S^m = Kp_t \int_0^t p.dt$, where $S$ is the sorption valve at time $t$, $p_2$ the momentary pressure and $m$ a (nearly) constant number of about 12, was found to hold for all press. and times over the exptl. range investigated. Except for a temporary derangement, the equation was still found applicable when the press. was suddenly increased or diminished in the middle of an expt. Similar expts. with $CO_2$ yielded analogous results. With this gas, however, the index was not const. but varied appreciably with the press. to which the sorption-valve was much more sensitive. While for strictly const. press. expts. with ammonia it was concluded that log $S$ would be a (nearly) linear function of log $(p_t^2)$, for $CO_2$, under the same conditions, log $S$ would be a (non-linear) function of log $(p_t^8)$. E. J. T.

**Optical glass.** J. W. FRENCH. *Proc. Roy. Phil. Soc. Glasgow,* **52,** 113–37(1924); *J. Soc. Chem. Ind.,* **44B,** 170(1925).—A brief history and description of the manuf. of optical glass. H. H. S.

**Allotropy of glass.** H. LE CHATELIER. *Compt. rend.,* **179,** 718–21(1924); *J. Soc. Chem. Ind.,* **44B,** 170–1(1925).—In a previous paper Le C. advanced an equation $\log \eta = -Mt + P$, representing viscosity as a function of temp., and inferring that below 800° glass exists in an allotropic form. He now compares the calculated values with the exptl. work of S. ENGLISH and indicates on a diagram the points corresponding with allotropic change for three different types of glass. H. H. S.

**English Pyrex glassware.** G. E. STEPHENSON. *Jour. Soc. Chem. Ind.,* **44,** 299–300 (1925).—The Wear Flint Glass Works, Sunderland, are the British licensees of the patents taken out from 1914 onward by the Corning Glass Works of this country. The process of manuf. is described. H. H. S.

**Annealing and re-annealing of glass.** W. M. HAMPTON. *Trans. Opt. Soc.,* **26,** 14–30(1924–5); *J. Soc. Chem. Ind.,* **44B,** 207–8(1925).—A series of equations is deduced showing the relationship between initial strain, strain due to cooling gradient, and final strain. The equations were applied to different types of glass of varying thickness. Conditions of re-annealing were examined with regard to temp. and for annealing and cooling times to be a minimum. The effect of errors in temp. meas. and in the rate of cooling is also studied. A scheme of annealing to cover the cases considered is given in tabular form. H. H. S.

**Glass in 1924.** E. A. COAD-PRYOR. *Ann. Rept. Soc. Chem. Ind.,* **9,** 214–25 (1924).—The most important work published during the year deals with viscosity and surface tension at high temp. (papers by WASHBURN, SHELTON and LIBMAN; and by S. ENGLISH). W. deals with soda-lime glasses, and E. with $Na_2O$, CaO, MgO, $Al_2O_3$, and $B_2O_3$ glasses. E. comments on the difficulty in handling magnesian glasses; they adhere to the Pt wire, or to the gathering-iron in working practice, and cannot be re-

moved by heating and quenching. Boric glasses, as noted by many writers, show a discontinuity in properties suggestive of the formation of a compd. more resistant than sodium borate or sodium silicate. Devitrification is the cause attributed to apparent anomalies in variation of viscosity with temp. in many glasses. GRIFFITH (*Phil. Trans.*, **221A**), using a highly aluminous glass (12% $Al_2O_3$) and a different method, found a surface tension 400 dynes per cm., as compared to WASHBURN'S 150 for soda-lime glass. An important paper by TOOL and EICHLIN gives evidence on the formation of mol. aggregates in glass at temps. near to the annealing temp. The work was carried out chiefly on a boro-silicate glass of annealing temp. 520°. The shape of the thermal curves below 500° and 600° and the quantity of heat evolved, vary considerably according to the previous heat treatment, but for any temp. there appears to be a definite condition of equilibrium which is a function of that temp., although at low temps. the mobility is too low to permit the glass to reach a state of equilibrium. Quenched glasses show a decrease of density if chilled from temps. above annealing temp., but an increase of density by 0.2% if chilled from 490°. No relation was observed between density and double refraction. The authors conclude that from any temp. a certain state of mol. aggregation is stable at that temp. Fatigue in glass is shown by BRAIN (*Proc. Phys. Soc.*, **36**, 81(1924)) in expts. on the piezoelectric phenomena shown by a number of dielectrics. On loading the specimens, charges were developed which with small loads were proportional to the load, but plate and window glass showed considerable fatigue after previous loading, the charges developed falling from 0.04 to 0.02 E. S. U. The elec. condy. of glass was found by Schönborn to follow the law log $W = V/T + C$, where $W$ is the spec. resistance, $T$ the abs. temp. and $V$ and $C$ constants depending on the compn. of the glass (see also Sutton and Silverman, *Jour. Amer. Ceram. Soc.*, **7** [2], 86(1924)). In all the glasses a discontinuity in condy. is observed at temps. corresponding to the well-known discontinuity in coeff. of expansion. The coloring action of S and Se in glass is attributed by FEDOTIEV and LEBEDEW (*Z. anorg. chem.*, **134**, 87(1924)) to the formation of sulphides and selenides. H. H. S.

**Some recent developments in furnaces and gas producers for glass works.** J. S. ATKINSON. *The Pottery Gazette and Glass Trade Review*, **50** [573], 430–2(1925).—This is a report of a paper read by A. at a meeting of the Society of Glass Technology. The "Torpedo" type of glass tank as developed by T. C. MOORSHEAD is described. The merits of this tank are listed as follows: (1) By eliminating the corners which the ordinary rectangular design fur. has, a more rapid and uniform circulation is obtained. (2) The construction of the bridge, flared out as it is from the center of the fur., makes it possible to ventilate or cool the side wall blocks much more efficiently. (3) The effective melting area is not reduced, but the vol. of glass in the tank is reduced, thus giving higher melting efficiency. The author also dealt with recent developments in gas producers, referring especially to the latest Chapman completely automatic producer, which is giving excellent results. P. D. H.

**Irish glass, old and new.** SIR HERBERT JACKSON. *The Pottery Gazette and Glass Trade Review*, **50** [573], 433–6(1925).—This is a report of a paper read by J. at a meeting of the Royal Society of Arts. Irish glass except for the blown varieties is unusually heavy. It has a peculiar depth of tone best described as a steel or gray-blue color. The cause of the gray color is unknown but it is probably due to some impurity in the lead used. Irish glass is tougher, stronger and more resilient than English. With regard to ring or sound, it has a distinct note of its own which is a vibration between two or three tones given forth with a throbbing effect. The ring of English glass is clearer and sharper. The new Irish glass described is still made by hand from old Irish recipes but is new in design. P. D. H.

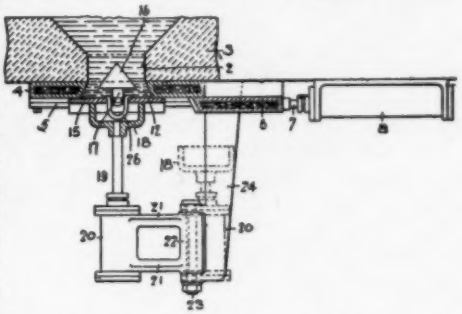
PATENTS

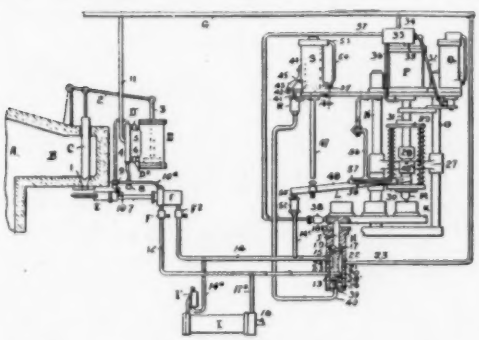
**Porous glass heat-insulating material.** J. H. DELANY. Brit. 222,965, July 12,

1923. Molten glass is treated with Zn vapor or other material which on condensation within the glass mass forms vacuous cavities. Building brick, receptacles for food and other articles may be formed from the resulting product. (*C. A.*)

**Hardening glass.** R. HIRSCH and SCHOTT & GEN. Brit. 223,353, Aug. 21, 1923. Glass articles to be hardened while hot are subjected to the chilling action of air blasts or are dipped in liquid. A glass is used having a cubical coeff. of expansion not exceeding 200 times $10^{-7}$. (*C. A.*)

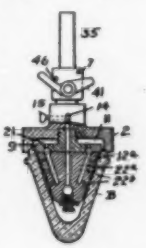
**Method and apparatus for casting plate glass.** FRANK E. TROUTMAN and CHARLES H. CHRISTIE. U. S. 1,530,629, Mar. 24, 1925. App. for casting plate or rolled glass comprising a glass-receptacle having a downwardly opening outlet, a fluid-cooled ring disposed immediately beneath and around said outlet, a hollow fluid-cooled knife mounted for reciprocation beneath said outlet, and means for withdrawing solidified glass formed in said outlet by the chilling action of said ring and said knife. The method of casting plate or rolled glass that comprises permitting glass to flow through a downwardly opening outlet, interrupting the flow of glass through said outlet, chilling a portion of the glass adjacent to said outlet, and removing and discarding the plug of chilled glass thus formed, thereby opening said outlet for the discharge of another portion of glass. The method of casting plate or rolled glass that comprises permitting glass to flow through a downwardly opening outlet, interrupting the flow of glass through said outlet, chilling the bottom surface of the glass within said outlet to form a holding plug for the glass thereabove, and removing said plug of chilled glass to thereby open said outlet for the discharge of another portion of glass.

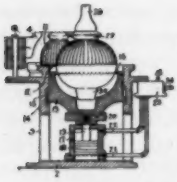




**Process and apparatus for controlling the feeding of glass.** WILLIAM J. MILLER. U. S. 1,532,254, April 7, 1925. The process of maintaining uniformity in gathers of glass produced by an automatic feeder which consists in regulating the amt. of glass in a gather being formed by the feeder by the amt. of glass in a preceding gather.

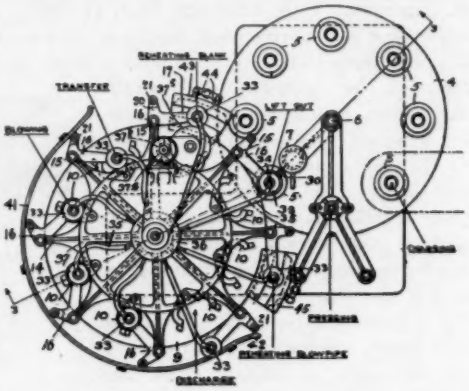
**Means for transporting glass articles.** WILLIAM J. MILLER. U. S. 1,532,255, April 7, 1925. In combination with mechanism for transporting hollow articles of glass, a vacuum gripper for said mechanism comprising a member contoured to circumferentially fit the wall of the article from without, a second member mounted in unison therewith and contoured to fit the wall of the article from within, said members being spaced apart to form a chamber which is closed by the article when the gripper engages an article, and means for applying a vacuum to said chamber.



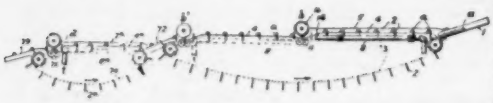


**Mold for making glassware.** FREDERICK W. STEWART. U. S. 1,532,162, April 7, 1925. A mold for forming articles of glassware comprising an upper mold part made up of horizontal swinging sections, the inner walls of said mold part having flutes formed therein terminating in scallops, a vertically movable lower mold part having scallops at its upper edge engaging with said first named scallops, a cylinder, a piston, connections between said lower mold part and said piston, and means for admitting fluid to points above and below said piston.

**Method of forming hollow glassware.** FREDERICK W. STEWART. U. S. 1,532,163, April 7, 1925. The method of forming hollow glassware consisting in providing a sticking-up tool, heating said tool, pressing a blank, sticking-up the open-end of the blank, introducing the blank into a blow-mold, and blowing the blank with air admitted through the sticking-up tool.

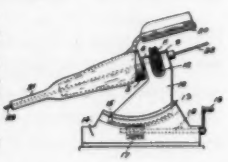


**Machine for making bottles or vials.** JOSEPH CONDE. U. S. 1,530,884, Mar. 24, 1925. In a mach. of the character described, the combination of a supporting trackway having a declivity, blank supporting means in register with said declivity, glassworking mechanism positioned to act on the blank while the latter is supported by said means, an endless conveyor for feeding the blank along said trackway with the blank supported on the latter, and means to operate said conveyor continuously, whereby the blank upon reaching the declivity descends the latter ahead of the conveyor and temporarily dwells on said supporting means during the action thereon of said glass-working mechanism whereupon the conveyor having caught up with the blank transports it onwardly from said supporting means.



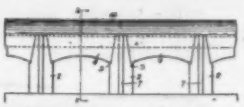
**Ornamental glass and process of making it.** FREDERICK GELSTHARP. U. S. 1,531,089, Mar. 24, 1925. A process of making ornamental glass, which consists in continuously forming, from a body of molten glass, a ribbon or sheet having a chilled, slightly roughened surface, and during such formation, and while the sheet or ribbon is setting, maintaining such a relatively high temp. for such time as to produce a bright lustrous finish without removing the surface irregularities which give it its rough appearance.

**Method of manufacturing glass rods.** PETER P. KUCERA. U. S. 1,530,728, Mar. 24, 1925. The method of continuously forming reinforced glass rods which consists in flowing molten glass along a hollow rotating support, controlling the rate of flow of the molten glass passing a rod longitudinally through the support and drawing a rod around the wire from the molten glass at one end of the support.

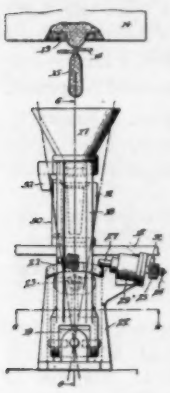


**Glass furnace.** FRANK E. TROUTMAN. U. S. 1,530,628, Mar. 24, 1925. A glass melting fur. comprising piers and arches each formed of a single block of refrac. mat.,

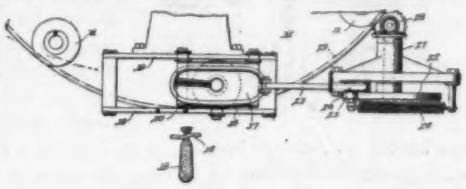
said piers and arches having horizontal projecting ledges formed on their inner faces, and a crown disposed between said arches and piers and above said ledges, said ledges serving to protect the adjacent surfaces of said crown and said arches and piers from the direct action of the hot gases in the fur.

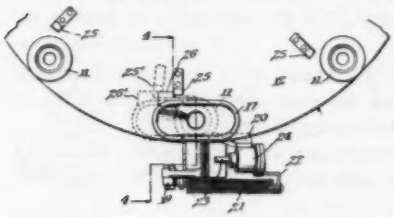


**Traveling funnel guide for glass-forming machines.** JAMES W. LYNCH. U. S. 1,531,559, April 14, 1925. A traveling funnel guide for forming machs. having moving molds traveling in a curvilinear path, comprising a supporting member having a universal joint mounting, means for guiding the supporting member in a path parallel to the path of movement of the molds, a funnel carried by said supporting member, and engaging means moving with the molds for engaging and moving said funnel in time with successive molds.



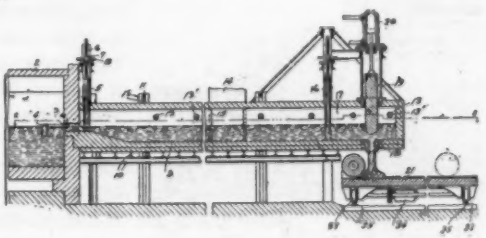
**Traveling funnel guide for glass-forming machines.** JAMES W. LYNCH. U. S. 1,531,560, April 14, 1925. A traveling funnel guide for forming machs. having moving molds traveling in a curvilinear path comprising a funnel carrier, a track adjacent to a portion of said path upon which said carrier is movable, a funnel mounted on said carrier, said funnel having an elongated hopper and a spout arranged above the plane of the filling openings of said molds, means to reciprocate said carrier and funnel to and fro on said track to coincide with the passage of successive molds, and means for tilting said funnel carrier as it moves to and fro to swing the funnel spout laterally sufficiently to keep it in alinement with the path of movement of said molds.





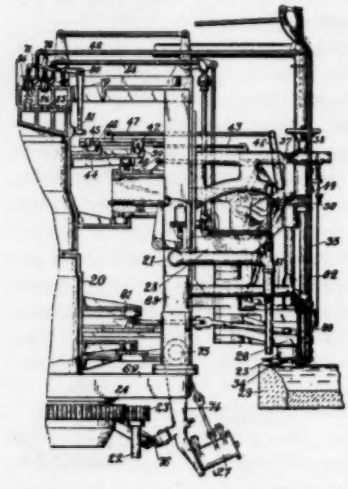
**Traveling funnel guide for glass-forming machines.** JAMES W. LYNCH. U. S. 1,531,561, April 14, 1925. A traveling funnel guide for forming machines having moving molds traveling in a curvilinear path, comprising a supporting member movable in a path substantially a chord of said curvilinear path, a funnel carried by said supporting member with its throat immediately above the open tops of said molds during their movement through the arc subtended by said chord, and engaging means moving with the molds for engaging and moving said funnel in time with successive molds.

**Process of making plate glass.** FRANK E. TROUTMAN and CHARLES H. CHRISTIE. U. S. 1,535,061, April 21, 1925. The method of casting molten glass that comprises flowing the glass through an outlet upon a casting table, advancing a casting table beneath said glass outlet, and

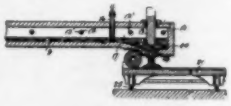


regulating the amount of glass received on said table by controlling the speed at which said table advances.

**Glass-forming machine.** THOMAS STENHOUSE and LEONARD D. SOUBIER. U. S. 1,534,036, April 21, 1925. In a glass forming mach., the combination of a mold, means to charge the mold by suction, a rock shaft, a cutter carried thereby, means to rock said shaft and thereby swing the cutter across the end of the mold to sever the glass, means to open the mold after the glass is severed, and a burner carried by said rock shaft and moved thereby into operative relation to the glass after the mold is opened.

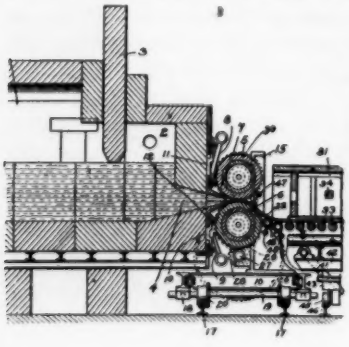


**Apparatus for making plate glass.** FRANK E. TROUTMAN and CHARLES H. CHRISTIE. U. S. 1,535,062, April 21, 1925. In apparatus for making flat glass, the combination of a melting fur., a shallow runway of materially greater length than width communicating with said fur., means independent of said fur. for controlling the temp. of the glass at the outer end of said runway, a receptacle adapted to receive glass from the outer end of said runway and having a discharge opening in its bottom, a casting table adapted to move beneath said opening, and means for forming the glass on said table into a sheet.



**Method of laying plate glass.** FRANK E. TROUTMAN and CHARLES H. CHRISTIE. U. S. 1,535,063, April 21, 1925. The method of laying flat glass on a grinding or polishing table that comprises lifting a plurality of pieces of glass by means of suction applied to the upper surface of the glass and fixedly limiting the relative upward movement of the upper surfaces of the said pieces so as to bring all of the said upper surfaces to the same level.

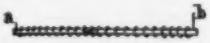
**Apparatus for laying plate glass.** FRANK E. TROUTMAN and CHARLES H. CHRISTIE. U. S. 1,535,064, April 21, 1925. App. for laying flat glass upon grinding or polishing tables, comprising a suction device adapted to engage and support the glass to be laid, and rigid seating means for permitting the surface of the glass engaged by said suction device to be alined in a definite plane.



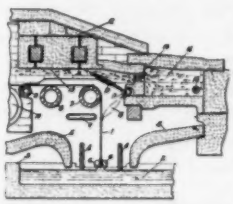
**Method and apparatus for making sheet glass.** FREDERICK GELSTHARP. U. S. 1,532,134, April 7, 1925. App. for forming sheet glass, comprising a receptable containing a bath of molten glass and having an outlet passage through its wall below the surface of the glass, a pair of fluid cooled rolling members spaced apart with the space therebetween adjacent the passage and in opposition thereto, a pair of lip members at the outer end of the passage projecting between the rolling members and serving as shields for the rolling members to reduce the area of contact between such rolling members and

the glass, and means for rotating at least one of the rolling members to govern the speed of movement of the glass therebetween.

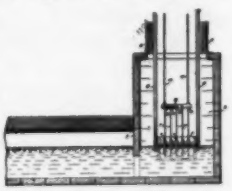
**Process for shaping glass tubes, more particularly tubes with rarefied gas, intended for lighting or luminous advertising.** GEORGES CLAUDE and JEAN MARIE EDOUARD DE BEAUFORT. U. S. 1,534,685, April 21, 1925. A process for shaping glass articles, comprising the successive steps of winding insulated wire around the article to be shaped; passing an elec. current through said winding to soften the glass; shaping the softened article while the winding is in place thereon; shutting off the current; and removing the winding from the shaped article after the latter has cooled.



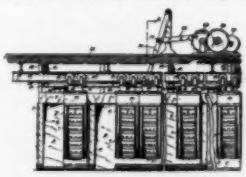

**Drawing and flattening sheet glass.** CLYDE W. BELDEN and INGLE B. BUSARD. U. S. 1,534,567, April 21, 1925. In a sheet glass drawing app., wherein the sheet is drawn vertically from a bath of molten glass and then bent into the horizontal plane, means for reheating the sheet in its horizontal run, comprising a member of heat radiating mat. under which the sheet moves, a source of heat for heating this member, and an auxiliary heating means adapted to interchangeably play against either the vertical run of the sheet or the radiating member.



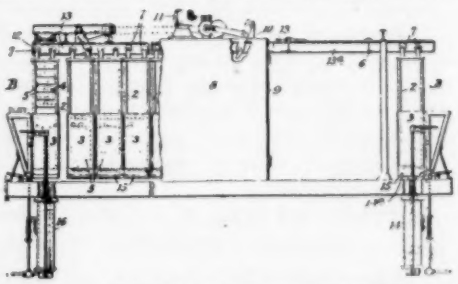
**Method of drawing glass and apparatus therefor.** WILLIAM E. HEAL. U. S. 1,532,182, April 21, 1925. The method of drawing glass which comprises lowering a box-like receptacle having spaced slots in its side walls, into a body of molten glass, raising said receptacle and maintaining it above said body of molten glass whereby the glass in said receptacle will tend to flow through said slots by gravity and return to said body of molten glass, and drawing sheets of glass from the glass in said receptacle.



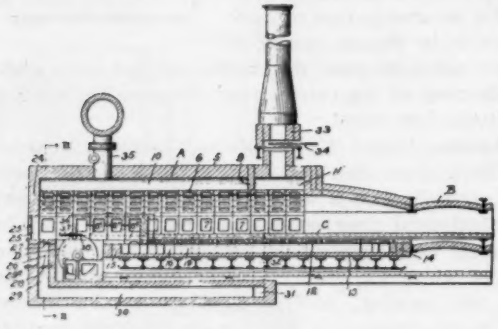
**Apparatus for annealing glassware.** GEORGE G. OLIVER and THOMAS STENHOUSE. U. S. 1,534,863, April 21, 1925. In app. for annealing glassware, an annealing leer having inlet and discharge ends and also having an antechamber, an annealing chamber and a cooling chamber arranged endwise of each other, dividing means between each two of the chambers, containers for a plurality of trays of glassware, a suspension for each of the containers, an overhead trackway along which each suspension moves, and means for moving each of the containers successively from chamber to chamber during the annealing operation.



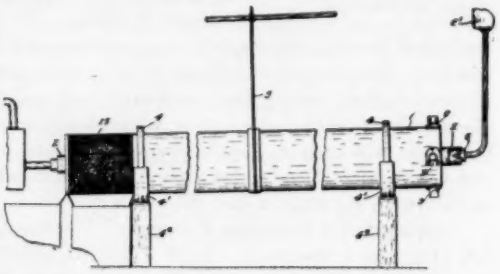
**Apparatus for tempering glassware.** GEORGE G. OLIVER and THOMAS STENHOUSE. U. S. 1,534,864, April 21, 1925. In app. for annealing glassware, a receptacle comprising an inner container and an outer container, the inner container having a closed top and bottom and a series of shelves having open sides, and an outer container having closed walls open at top and bottom, the inner container being adapted, when filled with ware, to rest in the lower portion of said outer container, the side walls of the outer container and the top and bottom of the inner container comprising a complete closure for excluding air during annealing.



**Annealing furnace and leer.** WALTER O. AMSLER. U. S. 1,533,298, April 14, 1925. A heating chamber for leers comprising an outer wall, an inner wall, which inner wall encloses a muffle chamber, means for circulating heated gases between the inner and outer walls, means for introducing articles at the side of the muffle chamber, and means for circulating the heated gases around the muffle chamber to the rear of the point where the articles are introduced into the muffle chamber. A heating chamber for leers comprising an outer wall, an inner wall enclosing a muffle chamber, an endless conveyor in the chamber, supporting wheels for the conveyor extending into the muffle chamber, vertical side flues for circulating heated gases between the outer and inner walls, and passages connecting those of the side flues adjacent the wheels whereby the portion of the muffle chamber into which the wheels extend may be heated by circulating gases thereabout.



**Rotary drier.** WILLIAM A. HARTY and FRANK W. MOORE. U. S. 1,531,438, April 14, 1925. A drier comprising a rotary shell, a screen at the discharge end of said shell, and an internal heating pipe extending through said screen and rotating with said shell.



## Heavy Clay Products

**The Carver economy wall.** ANON. *Brick & Clay Record*, **66** [4], 279–90(1925).—This is a very complete description of the new type of brick wall recently designed by William Carver. Numerous sketches explain every detail of construction. Tables are given showing strengths, costs and heat conduction properties of various walls. P. D. H.

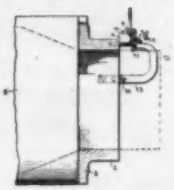
**Results of tests of combination hollow tile and reinforced concrete floor slabs.** A. H. STANG. *Brick & Clay Record*, **66** [4], 277(1925).—These results are of compression tests conducted at the Bureau of Standards. It is shown conclusively that the tile in combination floors is effective in helping to withstand the shearing and bending stresses to which the floor is subjected. It appears that the tile add about 50% in width to the concrete. That is, where a 4-inch joist had been previously used, a 6-inch could be used with safety. P. D. H.

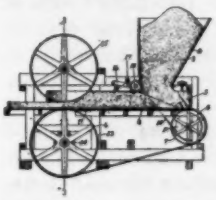
**Pressing and firing of dry press bricks.** P. THOR. *Tonind.-Ztg.*, **48**, 969–70 (1924).—A description particularly regarding the control of the moisture content. W. S.

**Why a drying plant alongside the kiln is preferable to one above the kiln.** RICHARD SEYDEL. *Tonind.-Ztg.*, **48**, 955–6(1924).—Eleven reasons why drying plant should be level with the ground. W. S.

PATENTS

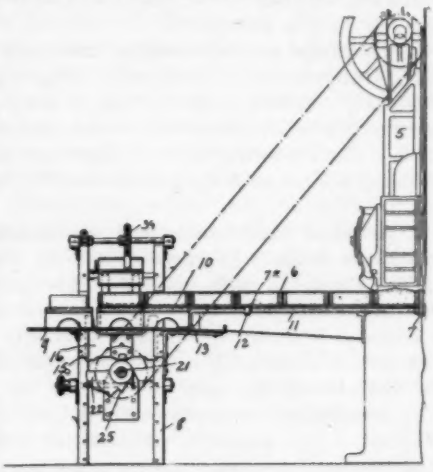
**Facing mechanism for tiles and bricks.** OSCAR B. ENEVOLD and ERICH H. ARNDT. U. S. 1,531,908, Mar. 31, 1925. A facing mechanism comprising a plurality of spaced combined guide and supporting devices adapted to be secured to the front of a die of a clay forming mach., a pair of spaced combined guide and retaining members adapted to be secured to the front of the die of the clay forming mach. and arranged to extend in close proximity to, forwardly and to one side of said devices, and a reciprocatory facing element interposed between said devices and members and slidably supported on said devices at the front thereof, said element positioned in the path of the clay as it leaves the mach. to act on one face of the clay.



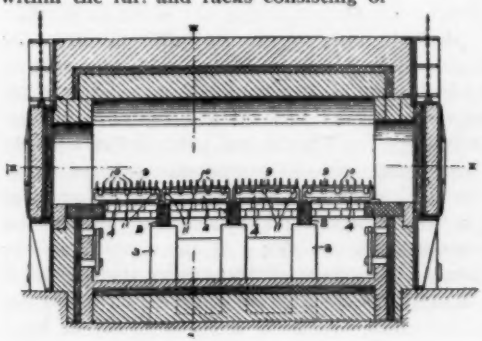


**Brick machine.** DAVIS BROWN. U. S. 1,534,768, Apr. 21, 1925. In a brick mach., a plurality of wheels for shaping the sides of a clay column, means for actuating the wheels and belts for feeding the clay to certain of the wheels, one of said wheels having a portion extending within the edges of two of the belts for compressing the clay.

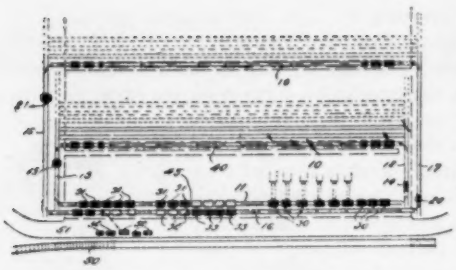
**Brick-molding machine.** MAURICE BRYAN LOOMIS and EDWARD BURROWS LOOMIS. U. S. 1,531,296, Apr. 21, 1925. In combination with the delivery table of a soft mud brick making mach. and bottomless molds therefor, a supporting structure adjacent the end of said table, pallets for receiving the filled molds from the delivery table, a driven shaft, cams keyed on the shaft, teeth on each of the cams, lifting plates for engaging the molds, lugs on said lifting plates coöperating with the teeth of the cams to jar the brick free from the molds and means for retaining the elevated molds above the pallets.



**Enameling furnace.** ALAN D. DAUCH. U. S. 1,532,621, April 21, 1925. An enameling fur. having in combination therewith a plurality of beams or members arranged in spaced relation within the fur. and racks consisting of a plurality of longitudinal sections provided with pins for supporting articles and detachably supported by said beams or members.



**System and apparatus for trafficking tile during manufacturing.** GEORGE W. DENISON. U. S. 1,531,739, Mar. 31, 1925. In a plant for mfg. ceramic products the combination of a closed cycle of trackage, said cycle including tracks whereby trucks carrying the product may traverse a drying oven,



and parallel stretches of tracks whereby the dried product carried by trucks on one track may be transferred to trucks on another track, the routing of which circumscribes the path of the first track and which includes a stretch of track traversing a firing oven.

## Refractories

**Research possibilities in refractories.** M. C. Booze. *Brick & Clay Record*, **66** [4], 294–6(1925).—This article deals with the methods of improving the quality and reducing the production costs of refracs. The following problems for invest. are discussed. Labor saving devices; miscellaneous plant equipment; auger machs. and dies; method of controlling water at pug mill or wet pan drying; firing; calcining; control of size; and purification of clays. P. D. H.

**New use for sillimanite.** W. J. Rees. *Jour. Soc. Chem. Ind.*, **44,** 359(1925).—Sillimanite may be used for making semi-permanent molds for repetition castings in iron, steel and other metals. The high refractoriness of sillimanite and its small drying and firing shrinkage when bonded with up to 15 or 20% fire clay renders it particularly suitable for this purpose. H. H. S.

**Centrifugal method of making small pots of electrically fused refractory materials.** F. S. Tritton. *Proc. Roy. Soc.*, **107A,** 287–90(1925); *Jour. Soc. Chem. Ind.*, **44B,** 208(1925).—Powdered MgO, $Al_2O_3$, or $ZrO_2$, is rotated in a cup-shaped mold and is meantime fused by an arc between two carbon rods dipping into the central part of the mold. The time required to produce a pot is 15 min. Tendency to form carbides, in the case of $Al_2O_3$ or $ZrO_2$, is eliminated by directing a stream of O into the mold. H. H. S.

**Action of blast-furnace and open-hearth slags on fire brick, and on silica and magnesite bricks.** J. Preller and V. Korber. *Chem. Listy*, **18,** 383–9(1924); *J. Soc. Chem. Ind.*, **44B,** 173(1925).—Corrosion is increased by a rise in the proportions of free FeO and MnO in the slag, by a decrease in the viscosity of the slag, and by an increase in free silica in the brick. Severity of corrosion is inversely proportional to the density of the brick and to the amt. of sillimanite formed in the parts of the lining in contact with the slag. H. H. S.

**Investigations regarding silica brick.** E. Steinhoff. *Stahl u. Eisen*, **44,** 1277, 83(1924).—The author investigates the influence of transformation of silica brick after firing (3 diff. types) on the stability in the kiln; tables curves and illustrations are given. W. S.

**Trace heat lost through walls.** M. L. Hartmann and O. B. Westmont. *The Foundry*, **53,** 219–20(1925).—The thermal condy. of carborundum brick was measured by the method of Dudley, using a wall built of stand. 9-in. brick laid with mortar of the same compn. The following conclusions were drawn: The thermal condy. of pure carborundum is const. for temps. from 650–1350°C. The thermal condy. of ceramically bonded carborundum increases with increasing temp. The thermal condy. of carborundum refracs. decreases with increase in % of fire clay bond, and the temp. gradient through a wall increases with increase in % of fire clay bond in the brick. The thermal condy. of fire clay is inversely proportional to the porosity. At any given temp. the thermal condy. of carborundum increases as the amount of heat energy transmitted is increased. With fire clay the condy. is independent of the amt. of heat energy transmitted. M. E. M.

**Refractories for oil-burning boilers.** T. S. CURTIS. *Mech. Eng.*, **67** [4], 299 (1925).—Two causes for short life of fire brick in oil-burning boilers are (1) softening under loads at temp. hundreds of degrees below m. p. and (2) spalling. Softening is due to incipient vitrification. Spalling is exaggerated to rapid htg. and cooling. A third destructive influence is the throbbing or pulsating of the oil flame. A brick has been produced from purified California clays which is dense, free from impurities and glazed with a sillimanite coating; an interlocking shape is provided to minimize the destructive effect of the vibration of the oil flame. C. J. H.

**Refractories in 1924.** W. J. REES. *Ann. Rept. Soc. Chem. Ind.*, **9**, 284–92 (1924).—Reference is made to papers published in *Jour. Amer. Ceram. Soc.* by BUCKNER, HENRY, PRESSLER, ROSE, NORTON, BOOZE and FLINT, ROBSON and WITHROW, and BOWEN and GREIG, and to the bibliographies of silica and magnesite refrac. published by this SOCIETY. The transmission of heat through refrac. was the subject of a number of papers. GREEN (*Gas. J. Suppl.*, July 9, 31 (1924)), shows that thermal condy. increases with temp. of firing, and at lower temps. decreases with increasing porosity. Brick with high grog content have at the higher temps., a higher FOURIER'S diffusivity and thermal condy. than those with low grog content, while the reverse is the case below 1000°. It is suggested that at high temps. transmission of heat by convection and radiation in the pore spaces increases. HALLIMOND has discussed the formation of eutectics and similar structures in slags and silicate melts. With fine-grained slags the pattern of the fret is best examined under vertical illumination, the minerals of low refractive index having the weakest reflecting power. It is pointed out that a "graphic" structure of interlocked outlines is not necessarily indicative of a eutectic. A similar structure is given by solid solns. homogeneous at the crystg. temp. The mech. strength of a refrac. at high temps. is frequently a detg. factor in its durability, and attention is being given by numerous workers to relationship between compn., texture, normal refract., and refract. under load. MELLOR considers that the difficulty in finding a relationship is due to a great extent to the difficulty in distinguishing between the two distinct types of fracture, the one due to a mech. breaking down of the mat., and the other due to gradual subsidence under the load. DALE states that the temp. at which subsidence under load begins is independent of the grog content, but the temp. at which complete breakdown occurs is lower with brick contg. grog than with straight clays. The discovery and exploitation of large deposits of sillimanite in India is regarded as a matter of first importance. The refractoriness of this native mat. is cone 38. The increasing use of silica brick for lining coke-ovens and the construction of gas-retorts indicates that this matl. will supplant fire clay or mixts. of fire clay and silica for these purposes. Spinel refrac. in this country of m. p. cone 38 are alluded to. H. H. S.

**Refractory materials.** V. C. FAULKNER. *Chem. Age.*, **12** [297], 179(1925).—A paper read before the Institute of Metals. The points emphasized in the paper were summarized as follows: (1) High fusion point, apart from chem. desiderata, is not the $\alpha$ and $\omega$ of a refrac. mat. (2) That the heat of condy. is perhaps equally important. (3) Plastic refracs. suffer from this defect, and should be incorporated with refracs. of better heat-conducting properties. (4) Cementing mats. should be kept to a minimum, and this can only be done by insisting on the dimensional accuracy of the brick used. (5) That both mass and local press. on the brickwork should be kept to a minimum, the latter being also helped by the dimensional accuracy of the brick used. (6) That refrac. walls should be twice coated with a refrac. cement, and that a fine finish should be given so as to obtain a glaze, with the object of (*a*) exposing a minimum surface to light and heat rays, and (*b*) a mat. under no real press. (7) That British silica brick are not fired at sufficiently high temp. and that as a result they expand too much on htg., which can preclude the use of plastic refrac. coatings. E. J. T.

PATENTS

**Production of surface layers on refractories which are metallic conductors and act as katalyzers.** ARTHUR WILHELM. Suisse Pat. 103,657, Oct. 10, 1922. On the surface or on the inner wall of refrac., which contain oxides of silicium, titanium, zirconium, iron, chromium or manganese in an atmosphere of H a light metal and an oxide of a light metal above the m. p. of the light metal but below the softening point of the refrac. are acted upon. Metallically conductive layers are produced. The products serve as elec. heat radiators; also as katalyzers. W. S.

**Composite quartz body.** ELIHU THOMSON. U. S. 1,532,002, Mar. 31, 1925. The method of making a plate of quartz having a regular, unbroken surface which consists in heating quartz sand in a mold to cause coalescence of the particles, thereby forming an opaque mass, and then facing said mass by local fusion with a layer of clear, homogeneous quartz.

**Refractory furnace lining.** DANIEL H. MELOCHE. U. S. 1,534,237, April 21, 1925. The method of protecting and repairing the refrac. lining of a fur. which consists in first heating the refrac. surface of the fur. to between 300° and 500°F, then painting the heated surface of the fur. with a wash containing not over 10% of sol. silicate in soln. and a considerable quantity of powdered fire clay in suspension, then heating the surface of the fur., then applying another thin coat of fire clay with the sol. silicate binder, again heating the surface of the fur. and repeating the operation until the desired thickness of fire clay is applied to the surface of the fur.

**Manufacture of silica bricks.** JOHN WILSON. U. S. 1,534,199, April 21, 1925. The herein described method of mfg. highly refrac. brick, which consists in intimately mixing china clay and lime each in a finely divided condition with natural siliceous stone also in a finely divided condition, the percentage of china clay being of the order of about 2.5% and that of the lime about 1.5%, and forming the mixt. into brick.

**Making refractory articles and the like.** ANSON GARDNER BETTS. U. S. 1,533,689, April 14, 1925. Process of making a refrac. article which consists in molding comminuted refrac. acid-insoluble mat. with an aqueous aluminum salt, in a metal mold, heating mold and contents driving off volatile matters, forming the contained mix to a solid physically dry article, and separating the same from the mold.

**Ceramic and refractory materials.** C. E. KRAUS. Brit. 224,257, May 1, 1923. The plasticity of ceramic materials, refractory compns., mortars, etc. contg. clay, kaolin, bauxite, flint, asbestos, $CaCO_3$ or similar ingredients is increased by the addn. of 5–20% of a highly colloidal earth such as bentonite, ehrenbergite, damonterolite or montmorillonite, with or without cork or other combustible substances which are burnt out to produce porous heat-insulation. (*C. A.*)

## Whitewares

**A new tile-glazing machine.** CLIFTON REYNOLDS. *The Pottery Gazette and Glass Trade Review*, **50** [573], 429–30(1925).—This is a report of a paper read by R. at a meeting of the Parent Section of the English Ceramic Society. P. D. H.

**A lecture on English pottery.** BERNARD RACKHAM. *The Pottery Gazette and Glass Trade Review*, **50** [573], 442–5(1925).—This is a report of a lecture given by R. of the Victoria and Albert Museum, South Kensington, England. P. D. H.

**Lead poisoning in English potteries.** *Jour. Soc. Chem. Ind.*, **44**, 353(1925).—The Ministry of Health states that the number of cases for the four years 1921 to 1924 were 35, 42, 44 and 47, making a total of 168 in all. H. H. S.

**Solubility of glazes and enamels used in cooking utensils.** G. W. MONIER-WILLIAMS. Ministry of Health, London, England, Report No. 29 (1925); *Jour. Soc.*

*Chem. Ind.*, **44,** 262(1925).—Representations having been made to the Ministry of Health that imported earthenware casseroles, dishes and similar articles were glazed with a raw lead glaze of high lead content, a number of these vessels were subjected to the action of hot 1% citric acid soln. and of various foodstuffs. While there is no serious risk of lead-poisoning arising from ordinary use in cooking, yet under certain conditions in domestic usage excessive quantities of lead may be dissolved. The imported ware showed lack of care in the prepn. and firing of the glaze. Investigations were also carried out on enameled hollow ware, on account of the outbreak of lead-poisoning in 1922 due to the use of lead-enameled tanks for the storage of beer, and it was found that the danger of injurious subs. being taken up by foodstuffs from domestic enameled ware was remote. This article is reprinted in *Chem. Age*, **12** [296], 155(1925) and *The Pottery Gazette and Glass Trade Review*, **50** [573], 439–40(1925). H. H. S.

**Ball clay.** HANS HIRSCH. *Tonind.-Ztg.*, **48,** 1155–7(1924).—Examples of rich clays which allow a diminishing of the plasticity to a great extent. Discussion of properties which allow one to determine numerically the practical value of the clays. Moistening, extension, tensile strength, softening under pressure, colloidal structure. W. S.

**Technical tests of raw materials in porcelain factories.** G. KLITZKE AND H. TROPITZSCH. *Keramos*, **3,** 505–7(1924).—A short discussion of the usual methods of testing to obtain an approx. survey of the qualifications of the raw mats. without having scien. accurate results. W. S.

**Heat balances of a porcelain round kiln.** G. KOPKA. *Keramos*, **3,** 495–8(1924).—The tests were made on a three-floor round kiln. Thermal efficiency of 17% of a furnace before and 32.5% after being rebuilt according to modern methods. W. S.

**Potters clay.** ARTHUR HOLLINS. *Chem. Age*, **11** [283], 10(1924).—A paper read by A. Hollins on improperly pugged clay and its effect on (*a*) the wage earning capacity of the operatives; and (*b*) the loss by defective wear to the employers. The various faults of pugging are pointed out. Suggestions were made for the storing and maturing of clay; and the grading of pugged clay to suit the several branches of the trade. E. J. T.

**China clay in a new pottery line.** ARTHUR HOLLINS. *Chem. Age*, **11** [283], 9 (1924).—Church Bank Pottery announced the successful making of British fire-proof cooking ware. The base itself is china clay, ball clay, calcined flint and stone, quartz, or feldspar. The ware is fine textured and highly resistant to thermal shock. E. J. T.

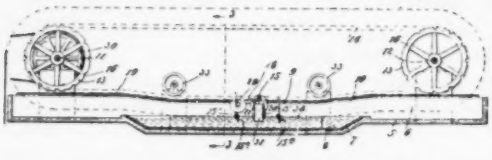
**Influence of the glaze upon the physical properties of porcelain.** E. GEROLD. *Keram. Rundschau*, **33,** 188–90(1925).—It was found that different glazes had a marked influence upon the following properties of high tension porcelain insulators: (1) modulus of elasticity, (2) tensile strength, (3) modulus of rupture, and (4) resistance to impact. The same glazes tested on different bodies influenced the properties of these bodies in the same way. The glazes did not only change the properties of thin bodies but also had a marked influence upon the thicker bodies. The influence of three glazes upon the properties of a porcelain was studied. It was found that all three glazes increased the elasticity coeff. Two glazes decreased and one increased the tensile strength. Two glazes decreased and a third increased the modulus of rupture. Two glazes decreased the resist. of the porcelain to impact while a third did not influence the body very much in this respect. Expts. were conducted to determine the influence of grinding these glazes off upon the properties of the porcelain. It was found that the modulus of rupture and the resistance of the body to impact became practically the same as the unglazed body after the glazes had been ground off. The elasticity coeff. was somewhat higher on the body from which the glaze had been ground off than that of the unglazed body. Expts.

were also conducted to determine the influence of slowly grinding off the glaze of the porcelain and then grinding off the outer skin of the body upon the tensile strength off the body. It was found that as the glaze was slowly ground off the tensile strength approached that of the unglazed body. As the outer skin of the body was ground off the strength of the porcelain decreased quite markedly, showing that the outer skin imparts strength to the porcelain. The influence of these glazes upon the properties of insulators 72 mm. thick was almost as great as upon bodies 20 mm. thick.

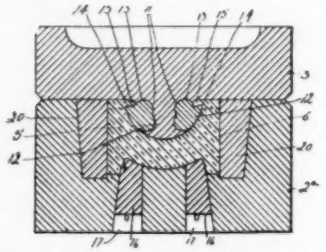
H. G. S.

PATENTS

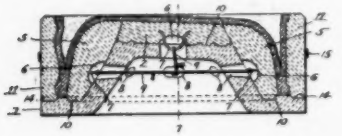
**Method and apparatus for enameling brick or tile.** JOHN FRANCIS BOORAEM. U. S. 1,531,839, Mar. 31, 1925. In combination with a trough adapted to contain an enamel bath, means for moving articles through said bath, said means including spaced article supporting devices, and additional means movable with said article supporting devices for effecting a movement of the enamel bath mat. at the same rate of speed as the speed of movement of the articles through said mat.



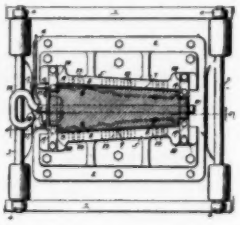
**Mold for pottery work.** WILLIAM BERNARD BUTLER. U. S. 1,534,155, April 21, 1925. A mold for producing articles from highly shrinkable mat., consisting of a base, a body, a face and a top section, so assembled as to be readily disassembled, an insert removably set in the base for forming a portion of the base of the article to be molded, two inserts removably set in the body for giving contour to the back of said article, an offset carried by the face section, two spline plugs removably fitted to said offset, said plugs and offset constituting that portion of the mold for forming the undercut inside of said article and an insert forming a portion of said offset.



**Bathtub mold.** ABEL HANSEN. U. S. 1,534,779, April 21, 1925. A mold for forming clay objects, comprising a core member constituted of a base having openings therethrough, and mold-forming sections applied thereto with means for securing the sections to the base and to each other.



**Apparatus for making porcelain legs.** ABEL HANSEN. U. S. 1,534,780, April 21, 1925. In a mold for forming porcelain legs in combination, a lower and an upper half, side guides in which said halves have vertical play, and end plates slidable on the side guides and having central orifices for holding a core rod.



## Equipment and Apparatus

**Applications of electric control for clay plants.** T. B. HEUSTIS. *The Clay-Worker*, **83** [3], 249–54(1925).—A car hump is described and shown in a sketch on which the motor is started automatically when a car is to be elevated and is stopped in a similar manner when the car has reached the top. An overhead crane and mechanical setter are described, as well as an automatic app. used for loading pallets of brick on drier cars. There is a de-

scription of a one-man elec. transfer car together with a complete sketch. This car is equipped with a reach arm motor which drives the transfer. An electrically driven reel cutter is described. The power for driving the cutter is taken direct from a variable speed motor, the speed of which is maintained at a fixed ratio to the speed of the belt by a differential governor. A new type of hacking mach. is also described. P. D. H.

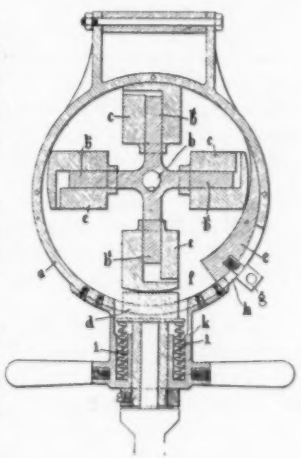
**Temperature measurements with thermoelements.** J. WÜRSCHMIDT. *Z. Metallkunde*, **16**, 271–4(1924).—Many of the values published for the thermoelec. power of thermocouples do not state whether they are mean values for 1° over a temp. interval or whether they are the values of the thermoelec. power for a difference of 1° at a definite temp., *e. g.*, the value for a Pt-Pt 10% Rh couple for 1° at 0° is 4.3, at 100° 5.18, and the mean value 0–100°, 4.74 microvolts. New detns. of the thermoelec. power for a no. of couples over the same temp. range show that the property is, within the limits of exptl. error, strictly additive. With constantan as the standard (0) the thermoelec. power of Ni is 21, V2A alloy 40, Fe 53, and chronin 59. Burgess found values on this basis for Ni 20, 10% Rh-Pt 24, and Pt 29. (*C. A.*)

**Fischer-Bauer's modification of the Fischer viscometer.** E. P. BAUER. *Chem. Ztg.*, **49**, 96–7(1925).—The Fischer viscometer (cf. *C. A.*, **14**, 3340) is not satisfactory for measuring the viscosity of materials like suspensions. B. describes an app. with which viscosities of all kinds of liquids can be measured with an accuracy of ±1 to 2%. The app. works on the principle described by Doelter and Sirk (cf. *C. A.*, **6**, 957) and by Albert (cf. *C. A.*, **18**, 2620). The time required for a counterbalanced sinker to fall through a known height of the liquid is measured. Relative viscosities are thus obtained. Absolute viscosities are detd. by calibrating the instrument with a liquid of known viscosity. (*C. A.*)

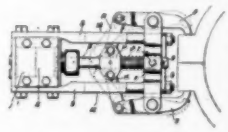
**A rapid weighing torsion balance.** RESEARCH STAFF OF THE GENERAL ELECTRIC CO., LTD. (E. M. EDEN and H. W. B. GARDINER). *J. Sci. Instruments*, **2**, 119–24 (1925). (*C. A.*)

PATENTS

**Impact device.** NICOLAS GEORGEVITCH. U. S. 1,531,549, Mar. 31, 1925. An impact device or hammer having an impact member slidable under the influence of centrifugal force and means for moving the impact member against the action of the centrifugal force and for suddenly releasing the same just before the moment of impact.



**Clamp for glass molds.** THOMAS STENHOUSE. U. S. 1,534,878, April 21, 1925. A clamp for molds, including a piston rod, a crosshead mounted for limited sliding movement thereon, clamping jaws pivotally mounted on the crosshead, means for moving the crosshead and jaws bodily forward to a fixed position, and means for causing the jaws to swing inwardly into clamping position after the determination of the forward bodily movement.



## Kilns, Furnaces, Fuels and Combustion

**Conservation of fuel.** CARL B. HARROP. *The Clay-Worker*, **83** [3], 255–60 (1925).—This article deals with the saving in fuel from the firing of clay products in

tunnel kilns. A table is given showing the types of ware fired in a number of tunnel kiln installations, the type of fuel used, the construction cost, the yearly saving and total saving in fuel. P. D. H.

**The economy of kiln insulation.** E. C. LLOYD. *The Clay-Worker*, **83** [4], 345–8 (1925).—It has been shown by actual tests that approx. 9% of the fuel used in firing may be saved by $4^1/_2$ inches of insulation on the kiln crown. With the side walls and bottom insulated the saving would be doubled. A sketch shows the method of insulating round down-draft kilns. The method of insulating a tunnel kiln is shown in a cut. P. D. H.

**Timely advice in firing (No. 2).** ANTON VOGT. *The Clay-Worker*, **83** [4], 344 (1925).—While it is impossible to save much fuel during water-smoking it is possible to save time by firing more rapidly. This is not likely to injure the ware if there is sufficient draft to carry off the steam as fast as it is formed. In order to produce sufficient draft a fur. should be built at the stack and kept burning until the water-smoking is completed. The time saved will pay for the fuel consumed in the stack fur. many times over. In order to determine when the ware in the kiln is dry it is much better to insert a rod in the bottom peephole of the door than in the stack flue, for the flue itself may be sufficiently damp to cause moisture to condense on the rod. Much time is lost and fuel wasted by firing too slowly during the oxidation period. Light frequent firings will advance the heat gradually and expel the carbon in the least possible time. Trials should be drawn, as the bluish vapor may be caused by the coal instead of by the carbon in the clay. P. D. H.

**The problem of firing.** A. V. BLEININGER. *The Clay-Worker*, **83** [3], 267–8 (1925).—It is possible that the system of firing with an induced draft is wrong in principle. The induced draft with its tendency to form streams of gases in the kiln and to induce an enormous leakage of air into the kiln through the many openings is not conducive to more rapid firing nor to an even heat distribution nor to fuel economy. Forced draft is suggested instead of the induced draft. This system would involve the introduction of the air to the furs. under the grates by means of a blower, delivering the air at from one-half to several ounces per sq. in. A positive press. in every part of the kiln instead of a negative press. or suction, would be more apt to accelerate the rate of firing from the very beginning of the water-smoking, to promote the oxidation and to insure a more uniform distribution of temp. with a mat. reduction in the firing time. It also eliminates the loss due to leakage of air into the kiln. This system would lend itself readily to the opern. of the kilns on a semi-continuous principle by connecting them. P. D. H.

**Fuel mixing.** R. C. GANGEWERE. *The Clay-Worker*, **83** [3], 254–5(1925).—This paper deals with the mixing of powdered fuel with clay. Anthracite coal and coke gives the best results. Ashes having an appreciable carbon content are also used. P. D. H.

**The C. F. B. patent enamel kiln.** ANON. *The Pottery Gazette and Glass Trade Review*, **50** [573], 419(1925).—The novel feature of this kiln consists chiefly in the formation of a ridge on the back vertical edge of the quarries, which are thus enabled to mortice into recessed mid-feather brick. The latter are built up in the kiln leaving a channel all the way around, and a sinuous course is provided along which the gases have to pass, it being impossible for them to enter the kiln chamber. Any existing kiln can be readily converted to the new system by the replacement of the quarries and mid-feather brick. P. D. H.

**Firing brick and tile with oil.** CARLTON GEIST. *The Clay-Worker*, **83** [3], 260–2 (1925).—This article deals principally with the Geist oil burner, its design and construction, principles of opern. and efficiency. P. D. H.

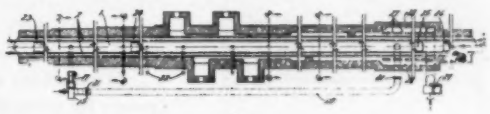
**The process of firing in shaft kilns with forced-in fuels.** ALBERT HAUENSCHILD. *Zement*, **13**, 495–9(1924).—The process is started by a gasification of the C, which reduces to CO with the $CO_2$ escaping from the mat. It burns on the surface of the pressed coal after escaping through its pores. If more C is forced in than the amt. equivalent to the $CO_2$ the atmosphere becomes reducing. This also happens if the pieces of the fuel are too large. To obtain the best conditions the clinker must be burned very porous. W. S.

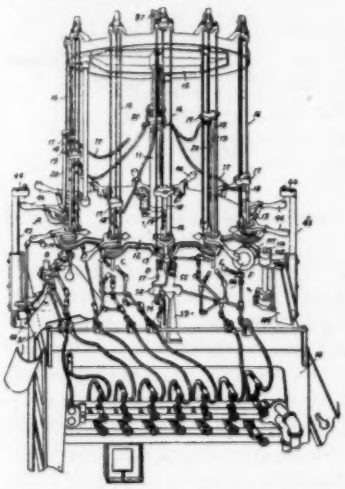
**A new type of mechanical stoker.** ANON. *Chem. Age*, **11** [275], 292(1924).—A new type, being a traveling grate compartmented air supply stoker, the "Underfeed Type C" which is on new lines and is both claimed to have eliminated riddlings altogether and to render possible the firing of refuse fuels in a fine state of division. The design is essentially that of a traveling laminated steel belt, having links of thin flat segments of steel only $^1/_4$ in. wide so that the air supply is highly sub-divided and the fuel does not fall between. The whole grate is watercooled. E. J. T.

**Cost of industrial heating.** D. J. DEMOREST. *Chem. Met. Eng.*, **32**, 381–2(1925).—A table is given showing the cost per 100,000 B.t.u. of 7 different fuels when fired in fur. operating at 400°, 1600° and 2300°F, both with and without recuperation. M. E. M.

PATENTS

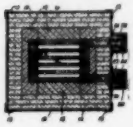
**Method and apparatus for treating clay ware in tunnel kilns.** CARL B. HARROP. U. S. 1,531,181, Mar. 24, 1925. The method of treating clay ware in a tunnel kiln which comprises passing the htg. gases in direct contact with the ware and controlling the velocity of the gases to regulate the amount of ht. imparted to the kiln walls and to the ware at different zones in the kiln. A tunnel kiln which is constructed internally with clearances between the ware setting and the kiln walls of varying area at different locations.



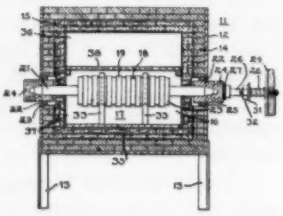


**Automatic glass-blowing machine.** HARVEY E. QUACKENBUSH AND CLEVELAND H. QUACKENBUSH. U. S. 1,532,077, Mar. 31, 1925. An air distributing device comprising two members movable relatively to each other one having an outlet port connected to a blowing mechanism and an inlet port and the other member having an outlet port adapted to register with the inlet port of the first mentioned member, an inlet port connected to a source of air pressure and a relief port, a closure for said relief port pivotally mounted adjacent thereto, a notched member mounted adjacent to said closure and means for causing relative movement between said notched member and said closure to cause a swinging movement of the latter into and out of engagement with said relief port. In a mach. for forming bulbs from glass tubing, the combination of a support having mounted thereon a series of holders each adapted to receive an end of a section of glass tubing, means adapted to operate upon the opposite ends of said tubing sections to fuse the same, and means connected to said holders for supplying air to said tubing sections at predetermined intervals in a series of puffs of predetermined duration.

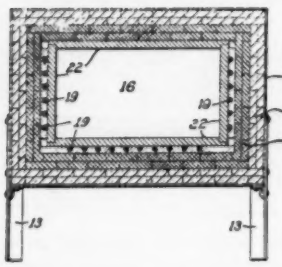
**Electric resistance furnace.** ORA A. COLBY. U. S. 1,533,224, April 14, 1925. In an electric-resistance fur., in combination, a plurality of refrac. walls surrounding a fur. chamber, a plurality of elongated refractory resistor members located in spaced-apart parallel relation, and a plurality of refrac. conducting blocks, each extending laterally of said resistor members and operatively supporting the ends of two adjacent resistor members and maintained in close operative engagement therewith by a superposed portion of said fur. structure.



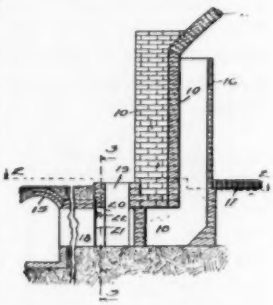
**Electric-furnace resistor.** ORA A. COLBY. U. S. 1,533,231, April 14, 1925. In an elec. fur., in combination, a resistor comprising a plurality of refrac. electrical-conducting bars, alternately of rectangular and of I-beam section, interfitting and supporting each other, and a plurality of spaced thin refrac. plates operatively engaging certain of said bars to support said resistor.

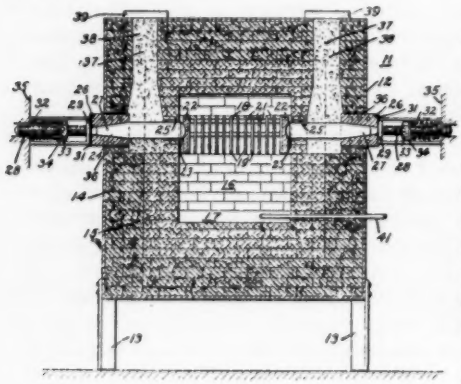


**Electric furnace.** ORA A. COLBY. U. S. 1,533,232, April 14, 1925. In an electric fur. in combination, a plurality of refrac. walls enclosing a fur. chamber and having a plurality of spaced recesses therein, cleats in said recesses having a surface extending into said chamber provided with a plurality of laterally extending grooves therein and a resistor member extending through said grooves and between said cleats.



**Waste-heat cooling system for periodic clay-burning kilns.** ROYAL L. ASH. U. S. 1,533,999, April 14, 1925. A waste heat cooling system comprising the combination of a kiln and a waste heat tunnel, with a flue arranged on the interior of the kiln, adjacent to the wall thereof, having its upper end open at the top of the kiln, a passage leading from the bottom of the flue to said tunnel, said passage having a port outside said kiln, a movable closure member in said passage between the port and the tunnel, and a false wall in the passage between the port and the flue.

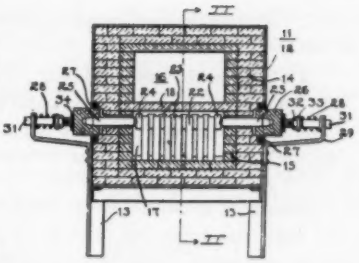




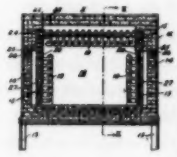
**Electric-furnace resistor.** GEORGE M. LITTLE. U. S. 1,533,254, April 14, 1925. An electric fur. comprising a plurality of relatively thin, flat, carbonaceous plates, and a plurality of relatively short carbonaceous members, of skeleton form in lateral cross-section, located in spaced relation between the flat faces of said plates, and means for producing a sooty vapor in said fur., said plates embodying means for reducing the deposit of soot on said members of skeleton form.

**Electric furnace.** GEORGE M. LITTLE. U. S. 1,533,255, April 14,

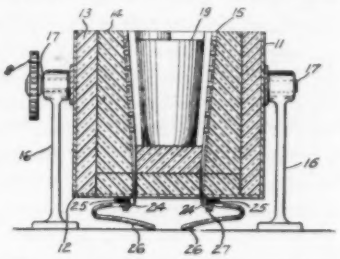
1925. An electric fur. resistor comprising a plurality of relatively thin, flat, refrac. plates, a plurality of current-conducting spacing members of relatively small area alternating with said flat plates and located adjacent the top portion thereof.

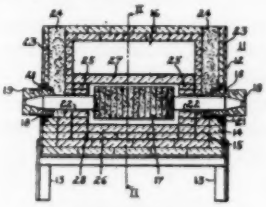


**Electric-furnace resistor.** THOMAS A. REID. U. S. 1,533,264, April 14, 1925. A resistor supporting means comprising a plurality of contiguous refrac. members, each having one end of L-shape for engaging and supporting a resistor member and means for loosely supporting said refrac. members.

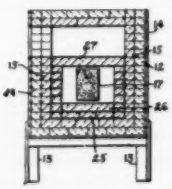


**Electric crucible furnace.** THOMAS A. REID. U. S. 1,533,265, April 14, 1925. In an electric fur., in combination, a refrac. casing, a plurality of relatively thin refrac. plates, of arcuate form in lateral cross-section, each plate having a plurality of relatively small spaced, alined, integral projections on the outer surface thereof and the said plates fitting within said casing, and a resistor member located between said plates and said casing and operatively engaging said plates at their outer surface only, the said portions thereof being maintained in proper operative position relatively to each other by the alined projections.





**Electric furnace.** THOMAS A. REID. U. S. 1,533,269, April 21, 1925. The method of protecting an oxidizable resistor member in a fur. chamber which comprises surrounding said chamber by a relatively thin layer of an initially granular mat. and heating said granular mat. to change the same to a substantially vitreous air-tight envelope.



## Geology

**Feldspars.** ANON. *Pottery Gazette and Glass Trade Review*, **50** [573], 415–7(1925).—Some valuable deposits of feldspar, claimed to be the largest known, are located near Verona, Ontario, Canada and are being worked at the "Richardson Mine." J. W. MELLOR reported the feldspar as being of remarkably high quality, the following being an anal. of a sample taken from the ground material as supplied to users: Silica, 64.36%; alumina, 20.06%; lime, 0.26%; magnesia, 0.26%; potash, 11.65%; soda, 2.74%; and iron oxide just a trace. P. D. H.

## Chemistry and Physics

**Determination of viscosities.** GUY BARR. *Chem. Age*, **11** [277], 347(1924).—A set of 4 oils whose viscosities at 25°C range from 0.14 to 6.5 poises and a series of Ostwald viscometers covering a larger range have been standardized. Abs. detns. were made on three oils using capillaries of 1.5 min. bore and the const. for a certain Ostwald instrument deduced (*a*) from these viscosities; (*b*) by a stepwise calibration starting from water; and (*c*) by calibration with sugar soln. The results agreed within

0.3%. The corrections required in the use of each of these methods are fully discussed in the report. E. J. T.

**Adsorption by precipitates.** HARRY B. WEISER. *Jour. Phys. Chem.*, **28** [12], 1253–64(1924).—A study was made of the adsorption during the pptn. by electrolytes, of negative arsenious sulphide sol and of positive hydrous ferric oxide and hydrous chromic oxide sols both in the presence and the absence of phenol and isoamyl alcohol. E. J. T.

**Ceramics in 1924.** W. J. REES. *Ann. Rept. Soc. Chem. Ind.*, **9**, 278–84(1924).—The reactions occurring during the firing of clays is still the subject of controversy. On the one hand, MELLOR'S hypothesis is that at about 500° kaolinite dissociates into an amorphous mixture of $SiO_2$ and $Al_2O_3$; on the other hand there are hypotheses like that of VERNADSKY, which implies a gradual change from kaolinite to sillimanite without the formation of free $Al_2O_3$ at any stage. Both sides agree that the final product after high temp. heating is a mixture of sillimanite and silica. BOWEN and GREIG'S paper on mullite, $3Al_2O_3.2SiO_2$, is discussed. VERNADSKY suggests that part of the water in kaolinite is "zeolitic water," and that the formula may be written $Al_2Si_2O_6(OH)_2.H_2O$. OSTWALD and PIEKENBROCK have endeavored to characterize clays by viscosity measurements on suspensions. They found that factors other than temp. and concentration influence the values obtd. Comparisons should be made not at a definite concn., but by the construction of a viscosity-concn. curve by measurements after repeated dilution of the original suspension. There are indications of an optimum quartz content varying with the size of the quartz particles. The difference in clays and kaolins after mechanical treatment suggests that in kaolin suspensions viscosity is detd. by size distribution of particles, while in clays the principal factor is a stronger power of hydration and swelling. JOSEPH and HANCOCK have investigated the relationship between composition and properties of clays in homogeneous preparations obtd. by dialyzing, or repeatedly filtering through collodion, the flocculated water-suspensions. It is shown that the $SiO_2$:$Al_2O_3$ ratio is the most important chem. constant of a clay. This ratio is related to the chem. reactivity of the clay to NaOH and neutral electrolytes, the development of acidity in the latter case being regarded as a special case of base exchange. They propose to measure plasticity by means of some property which is modified by ignition and by electrolytes—*e. g.*, the moisture equivalent. The purification of clays by sedimentation has been discussed by HIND. He considers that sedimentation after deflocculation notably reduces the amt. of iron in the clay but not $TiO_2$, alkalis, and alkaline earths. Sedimentation gives a finer grained product, increases contraction on drying and firing, and increases refractoriness. H. H. S.

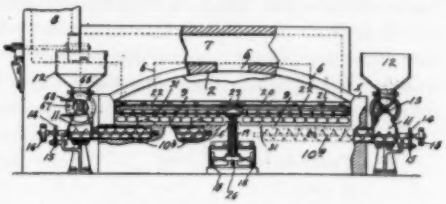
**Frost cracking.** A. BIGOT. *Compt. rend.*, **180**, 287–9(1925); *Jour. Soc. Chem. Ind.*, **44B**, 171(1925).—A specimen of black Etruscan ware cracked on exposure to cold; this was due to insufficient dehydration of the colloidal clay, because a portion which had been heated to 850° did not show the effect although its porosity was increased. Brick of porosity 55%, after heating to 1200° so that all the colloids were pectized, did not crack. If a mat. ground to an impalpable powder, gives colloid reactions, the mat. will tend to crack. H. H. S.

**Observations on structural-chemical silicate formulas and crystallographic-chemical decomposition and rearrangement of mica by dehydration, oxidation and reduction.** F. RINNE. *Ber. Verhandl. Sächs. Akad. Wiss. Leipzig*, **76**, 261–71(1924).—Muscovite and biotite were heated to 1000° in $N_2$ and in air and the latter was subsequently reheated in $N_2$-$H_2$ at the same temp. Comparison of the optical and Röntgenographic properties in the original and heated specimens led to the conclusion that in dehydration no change of crystal structure takes place. Oxidation is accompanied by marked change of optical properties but subsequent reduction completely restores the

original properties. This is caused by deformation of at. shells through loss or gain of electrons in the reversible transformation $Fe^{II} \rightleftharpoons Fe^{III}$. The orthosilicate formula of mica cannot be regarded as certainly valid structurally since it takes no account of the fact that dehydration and oxidation and reduction of Fe are structurally insignificant phenomena. (*C. A.*)

PATENTS

**Process of making chromates.** GEORGE P. FULLER. U. S. 1,531,088, Mar. 24, 1925. The process of making chromates which consists in roasting, in an oxidizing atmosphere, a mix comprising a chrome ore, an alkali metal carbonate, and a relatively infusible alk. absorbent, at a temp. above the fusing point of the alkali metal carbonate, submitting the mat. thus obtained to successively lower temps. until it has cooled below the fusion point of the alkali metal chromate formed, and during this cooling agitating the mat. until a granular product is obtained.



**Process for the treatment of leucite.** BIRGER FJELD HALVORSEN, HANS JOACHIM FALCK, THOR MEJDELL, and ØYSTEIN RAVNER. U. S. 1,531,336, Mar. 13, 1925. The process of treating leucite which comprises dissolving the leucite in dilute nitric acid and neutralizing the acid soln. obtained thereby, evaporating and cooling so that mixed crystals of nitrate of potassium and nitrate of aluminium are pptd., that have an average content equal to $KNO_2Al(NO_3)_2 9H_2O$.

BOOKS

**Textbook of metallography, chemistry and physics of the metals and their alloys.** G. TAMMANN. Trans. from third German edition by R. S. DEAN and L. G. SWENSON. Pp. 388. New York: Chemical Catalog Co., 1925. Price $6.00. H. H. S.

**Report of the progress of applied chemistry.** Vol. 9, 1924. London: The Society of Chemical Industry. Pp. 700. Price 7s. 6d. to members, 12s. 6d. to non-members. H. H. S.

## General

**Elimination of waste—simplified practice, what it is and what it offers.** This booklet may be obtained from the Government Printing Office, Washington, D. C. for ten cents. It shows what the Dept. of Commerce will do in coöperation with industries on this important subject. It shows further what various industries have already accomplished by simplifying and standardizing sizes and varieties. P. D. H.

**A visit to the osmosis plant at Carlsbad.** S. R. HIND. *Pottery Gazette and Glass Trade Review*, **50** [573], 427–8(1925).—This is a report of a paper read by H. at a meeting of the Parent Section of the CERAMIC SOCIETY. The plant described is that of the Carlsbad Kaolin Electro Osmosis Co., at Porchezan, Chodau, near Carlsbad, whose works manager is Director W. Meyer. A flow diagram of the plant is shown. P. D. H.

**Stone decay.** J. J. FOX AND T. W. HARRISON. *Jour. Soc. Chem. Ind.*, **44**, T145–T9(1925).—The injurious agencies which promote decay of stone may be put into 3 classes: (*a*) Atmospheric action of a mechanical nature, (*b*) chem. action, (*c*) living organisms. (*a*) The effects of weathering on poor stone are well known, but with sound stone weathering is of little consequence, and may enhance the appearance of the building. (*b*) The most serious cause of decay is the conversion of carbonate into sulphate and of cryst. sodium sulphate. (*c*) Lichens and mosses break up the surfaces of the stone, not only by the growth of their rootlets and hyphae, but also by the sol-

vent action of the carbonic and organic acids produced by them. There is no suggestion, however, that the action extends below the surface layer. *Bacterial action* is regarded by the authors as not proven. A universal stone preservative is regarded as difficult if not impossible. H. H. S.

**The Industrial Institute of Great Britain** (*Jour. Soc. Chem. Ind.*, **44,** 338(1925)), has been formed for the study of the fundamental problems of industry. It will include statesmen, financiers, employers, trade unionists, scientists and university representatives. The principal object of the Institute is "to develop a descriptive science of the working of the industrial system, including production, distribution, and finance, especially from the point of view of human relations and ethical considerations, and to strengthen the foundations of the science of industrial ethics." It also proposes to promote research into these questions which touch the relations and interests of the groups into which the development of the industrial system has divided the nation. H. H. S.

**The Pasteur fund.** *Jour. Soc. Chem. Ind.*, **44,** 358(1925).—The result of the collections on behalf of the scien. lab. of France during the Pasteur celebration in 1924 was to raise a fund of 12 million francs. H. H. S.

**The "Murray" wall. Water cooled combustion chambers.** ANON. *Chem. Age*, **12** [291], 29(1925).—The "Murray" tube consists essentially in constructing the two combustion side walls of 4-in. steel tubes, placed close together, through which the boiler feed-water circulates entering a common header at the bottom and being discharged into the boiler through corresponding headers at the top. Boiler plant efficiencies of 92% have been obtained on short tests and 90% for continuous performance. E. J. T.

**The internal combustion boiler.** O. BRUNLER. *Chem. Age*, **12** [296], 150–2 (1925).—A discussion of a paper presented on a boiler in which the flame is burned in the water of the boiler. Oil and air are fed in proper proportions into the boiler below the water level and combustion takes place with the flame in direct contact with the water. Unusual efficiencies are claimed. The system is also applicable to evaporating plants. E. J. T.

**The kaolin deposits of Furtei, Sardinia. Quality and analysis of china clay deposits.** ANON. *Chem. Age*, **11** [275], 15–6(1924).—The Furtei pits were opened in 1917 and prior to the British industrial crisis their production was 10,000 metric tons. Analyses show the kaolin from the various pits is practically free from alkali, lime and magnesia. Iron oxide in the form of ferric oxide in the calcined clay is never more than 1.85%, silica 57 to 68%; alumina 30 to 43%. The loss at red heat is 5 to 7.5%. E. J. T.

PATENT

**Diatomaceous earth product.** R. CALVERT, K. L. DERN and G. A. ALLES. Can. 245,938, Jan. 6, 1925. Diatomaceous earth is mixed with a halide of an alkali-forming metal to lower the sintering point of the clay present, and the mixt. is calcined. Cf. *C. A.*, **18,** 2949. (*C. A.*)

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## BOOK REVIEW

**Testing of Fire Clay Brick with Special Reference to Their Use in Coal-Fired Boiler Settings.** By R. F. GELLER. 1925. 42 pp. Technologic Paper No. 279 (Part of Volume 19) of the Department of Commerce, Bureau of Standards, Washington, D. C.

As the result of a conference, held at the Bureau of Standards, at which Government representatives and users and producers of fire clay refractories were present, 42 commercial brands of representative domestic refractories were obtained for labora-

tory testing through the coöperation of Stone and Webster. A field survey report was also obtained through the coöperation of this firm.

Only the so-called first quality fire brick suitable for use in coal-fired boiler settings were tested. The laboratory tests consisted of an endurance test, a reheating test, a quenching test, a load test, a softening point determination and an analysis of the brick both chemical and petrographic. The data contained in the field survey report cover the boiler rating type and load factor the year refractories were purchased and number purchased annually, the actual life and nature of failure of the refractory in the various locations of the boiler setting, the kind and quality of fuel used, the fusion point of the ash, and the type of stoker.

The refractory specimens were supplied by 60 power plants representing all of the important industrial districts of the country. A list of the plants is given together with the brand of specimen submitted by each.

The laboratory tests are briefly described as follows:

1. Endurance Test. This was made in two ways:

(*a*) The brick were placed on end in a gas-fired furnace and subjected to a temperature of 1450°C for 72 hours, two bricks having been tested simultaneously.

(*b*) The brick were laid flat, supported on a 7-inch span, loaded at the center with a 5-pound brick bat and subjected to a temperature of 1450°C for 72 hours. Two bricks of each brand were used in the test. This heat treatment was equivalent to the softening point of cone 19.

2. Reheating Test. This consisted of subjecting seven bricks of each brand to a temperature of 1400°C for 5 hours. This heat treatment was equivalent to the softening point of cone 15.

3. Quenching Test. This test followed in principle the tentative A.S.T.M. method, serial designation C38–21T, and was conducted on brick which had been reheated at 1400°C for 5 hours. Three kiln temperatures were used, *viz.*, 850, 1100 and 1350°C and five bricks from each brand were quenched from each temperature.

4. Softening Point Test. This was carried out according to the A.S.T.M. standard method, serial designation C24–20.

5. Load Test. This was carried out according to the A.S.T.M. standard method serial designation C16–20. This test was also given the following variations: (*a*) The brick were held under load at 1350°C for 10 hours instead of $1^1/_2$ hours, (*b*) brick preheated at 1400°C for 5 hours were held under load at 1350°C for $1^1/_2$ hours, (*c*) brick preheated at 1400°C for 5 hours were held under load at 1450°C for $1^1/_2$ hours.

6. Supplementary Tests.

(*a*) Absorption Determination.

(*b*) Petrographic Examination (after various heat treatments).

(*c*) Chemical Analysis. Iron oxide, alumina and silica determined.

(*d*) Erosion Test. This was done by subjecting the brick to a temperature of 1450°C for $1^1/_4$ hours, during which time $1^1/_2$ pounds of finely ground slag was introduced into the path of a flame and caused to impinge on the specimens.

The kiln used in making the endurance, reheating and quenching tests was a gas-fired recuperative, semi-muffle type. The furnace used for softening-point determinations was of the carbon resistance type.

For temperatures not exceeding 1350°C platinum-platinum rhodium thermocouples were used for measuring the temperature. For higher temperatures, an optical pyrometer was used by sighting into the open end of a sillimanite tube.

The results of the laboratory work seem to justify the following conclusions:

1. While the results obtained from the endurance test are of interest, simpler and less costly methods might better replace it.

2. The constant-volume test, as a preliminary step to quenching, provides valuable absorption data which have a bearing on the resistance of the brick to spalling.

3. The quenching test using 850°C as the furnace temperature is a reliable means for judging comparative resistance to thermal shock.

4. The softening point is of primary importance because of the many failures due to fusion and erosion.

5. The load test justifies itself as a means for determining whether or not an aluminous refractory is sufficiently well fired to resist a heavy load when applied during the initial heating of the installation.

6. It was found possible to improve the value of the load test by preheating the specimens.

7. The tests favor brick made by the dry-press process.

8. The chemical composition serves as an indirect measure of the softening point and resistance to spalling.

9. Petrographic examination can generally be substituted for chemical analysis, especially if the softening point is known.

10. The erosion test is of value if it is continued for several hours and if the proper slag is used.

The results of the field survey were as follows:

1. Refractories in the suspended arch fail principally through spalling.

2. In every location in the setting the failures are due mainly to erosion.

3. Conditions in the side and bridge walls were found to be very similar.

4. Walls which had lasted two years or longer showed high resistance to spalling.

5. The abnormal number of failures were found in connection with the use of the chain grate. This may be due to higher efficiency with the resulting higher temperatures.

There was found to be no apparent relation between laboratory and service results, since no two brands were subjected to the same service conditions.

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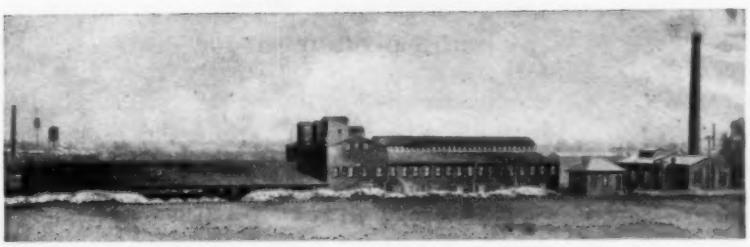

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**A Monthly Publication Devoted to Proceedings of the Society, Discussions of Plant Problems, Discussions of Technical, Scientific and Art Questions and Promotion of Coöperative Research**

**Edited by the Secretary of the Society Assisted by Officers of the Industrial Divisions**

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**Vol. 4** **June, 1925** **No. 6**


# EDITORIALS

## PROFESSIONAL CERAMICS

Ceramics is being more generally recognized as a profession. More universities are considering giving courses in ceramics to train men for industrial service.

Professional ceramics is the using of science in the making of marketable wares of specified character and quality. A ceramist is one who has the knowledge, vision and art required to produce ceramic wares. His capability to meet the ever changing trade conditions, tastes and specifications is in direct ratio with his ceramic knowledge, vision and skill.

Obviously the making of each kind of ceramic ware calls for a peculiar combination of facts, direction of vision and construction skill. With the same fundamental training and information each ceramist will use special knowledge of materials and processes according to the kind of ware produced. Continued employment in the production of one type of ceramic ware very soon makes him a specialist, that is, he is better informed and is more skilled in the making of a certain type of ceramic ware although employing the same facts and concepts used in all lines of ceramic manufacturing.

It remains as a truism, however, that the more thoroughly trained the professional ceramist is in finding and using science fundamentals, the more largely developed his ability to vision service or trade requirements and

the more skilful is he in fabrication, the broader at all times will be his industrial capacity to produce and the more effective will he be as a specialist.

Since chemistry, physics and mathematics deal with the fundamental facts and relations of all matter and materials used by ceramists, as by all industrial scientists, these are the foundation of our ceramic science. The more thoroughly trained in these the larger will be the capacity and vision of the professional ceramist. A university course of ceramic instruction should provide a thorough training in chemistry, physics and mathematics. A high school course should have enough training in these fundamentals to acquaint the pupil with the more basic facts and laws but especially to give a vision of the relations of matter and materials used in ceramic ware and ceramic processing. These sciences are fundamental to engineering and art. Engineering is more particularly and almost wholly the using of these science fundamentals in the devising of means and methods of fabricating marketable wares. Art deals with form and decoration but employing ceramic materials compounded and prepared. These same fundamental sciences (chemistry, physics and mathematics) are essential to the ceramic artist who is to attain the greatest possible breadth of vision and capacity to accomplish.

If professional ceramics is based so almost wholly on the fundamental sciences it is natural to ask why should the universities give special courses in ceramic science, engineering and art? The answer is found in the need of focusing on the fundamental facts concerning the materials and processes used in production of ceramic wares of specific kind and quality. Ceramics uses a limited lot of raw materials. Its processes of fabrication are peculiar. It is a specialty of definite limitations yet so broad and with such complexes as to exceed capacity of an individual to survey and know completely.

University courses of instruction are for the purpose of specializing in the application of science fundamentals to the employment of a limited variety of raw materials in the production of silicate ware of definite sorts.

Professional ceramics has gone a long way in the finding and applying of fundamental facts regarding ceramic materials and processes. To this the university instruction has until now been almost wholly devoted. We know a great deal about the industrial possibilities of ceramic materials and mixtures and a great deal of the engineering employed in ceramic processing. Our universities have been wise in concentrating on this particular phase of professional ceramic training for there was much and there is yet much to discover about materials and processes. There has been a great need for this knowledge and there is yet a great deal to be learned. But certainly the equipment of a professional ceramist would not be in

balance if he has not been trained to vision, to measure and to produce wares for definite purposes. And for too long a while has the professional preparation of a ceramist neglected the need of form, color and design. We are in need of ceramists of vision, one who can anticipate service and market demands. Our universities have not been giving this most needed training.

How long will American ceramists have to be trailing in the production of ceramic products of specific quality? Is not the answer until our ceramic technologists are trained to vision, produce and to measure product properties? Does not the situation warrant redesigning of the collegiate courses so as to stress product rather than materials? Should not the fundamental science facts, concepts and methods be used in studying products as they are now being employed in studying materials and mixtures.

Our plea is for professional ceramists trained to vision ceramic products and with knowledge of how to produce to specifications.

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## CERAMIC EDUCATION PROGRAM

One of the chief purposes of the AMERICAN CERAMIC SOCIETY is to promote ceramic education. The number of ceramic schools and their territorial distribution need not be considered. The justification for ceramic schools in various localities is based on local needs and hence is a local rather than general or national interest. Whether there are a sufficient number of ceramic schools or too many, and whether all localities are being adequately served are questions having little or no place in the general question "what this SOCIETY should promote."

All promotional activities of this SOCIETY are given direction by the most urgent industrial needs. The purpose of the SOCIETY'S promotional activities in ceramic education is to obtain a consideration by thoughtful people of how ceramic schools may render the most needed and timely service to the ceramic industries, and how the industries can collaborate with the schools. There is no possible criticism of the intent of the directors of the ceramic schools. They aim that their schools shall serve effectively.

The importance of ceramic education has prompted the Committee on Education to arrange a symposium for the 1926 Annual Meeting at Atlanta. The first general session will be devoted to it. A round robin mail discussion is to be conducted in anticipation so the facts will be better known. Mature judgment is wanted and this will be possible only after the manufacturers and the school instructors have developed the facts. This subject is worthy of a hearty and thoughtful participation by all members of the SOCIETY in this important conference.

## PROFIT IN MEETINGS

In July this SOCIETY will have a summer excursion meeting in Canada and will hold the Annual Meeting in Georgia next February. These meetings are for definite purposes. If the value received did not warrant the time and expense of attending they would not be so largely attended.

The purposes of these meetings are many but in general they are to promote ceramic research and education. The more each learns, the broader our knowledge and acquaintance, the greater facility we have to acquire and to accomplish. With the increasing numbers of those who know from experience and experiments there is an increasing opportunity in these meetings to obtain at first hand records of things proven and an appreciation of things yet to be done. A week at one of these meetings is worth in information and inspiration more than months in the shop or laboratory. These meetings are the most effective means of promoting research and education because they are intensively personal.

The men who participate in the programs and in the clubby informals have entered ceramics with a widely varied preparation. All of them are thinkers naturally and many have had years of manufacturing experience. Several have thought and studied their way through the "school of hard knocks" always focusing on their customers' ideals. They want explanations of the facts as they know them. A vast amount of the recorded ceramic knowledge has been initiated by recitals of the experiences and findings of the pupils from the school of hard knocks.

There are several who have entered the ceramic industries as chemists, physicists and engineers. They have had a broad fundamental training and always have unorthodox viewpoints. Contact with these men stimulates thought and enlarges vision. They have well trained minds and a fund of knowledge sufficiently dissimilar to be very inspiring when dealing with ceramic problems.

Technologists, engineers and artists from all sorts of ceramic industries convene at these meetings. One need take no more than a cursory inventory of the new ideas recently applied but originating from a wholly dissimilar industry to realize the value there is in exchanging ideas and recitals of experiences with men engaged in the different ceramic industries. The foundry and the clay shop continue to reciprocate in new processes, devices and control methods.

The managers, salesmen, engineers, miners, scientists and teachers complete the facility to obtain a refreshing vision of what must be done to increase sales. This combination will head all considerations in terms of product. The school instructors and the bureau investigators have been investigating product from the science viewpoint and by scientific methods. They have concentrated either on quality of product or economy

in production. They depend on these meetings to obtain the sales viewpoint so necessary in research. They have basic facts regarding the product which the salesman must have if he is to most effectively present his wares and most intelligently bring to the factory the new demands.

A week spent at one of these meetings is of more value than several weeks in the shop or laboratory. The broadening opportunities at these meetings would require many weeks and miles of traveling to equal. It pays to attend the meetings of the AMERICAN CERAMIC SOCIETY.

# PAPERS AND DISCUSSIONS

## SAVING FUEL IN FIRING COMMON BRICK[1]

By W. D. Richardson

ABSTRACT

Requirements of economy and fuel conservation, and incidentally the elimination of the smoke nuisance, make it necessary for America to follow the lead of Europe in adopting the regenerative continuous kiln of some kind for the burning of all clay products. For common brick the most practical and economical kiln is the annular kiln, a modification of the original Hoffman "Ringofen."

With simple automatic stokers and induced draft there is more rapid advance of the burning of the annular kiln and a greater saving of fuel. The compartment kiln and the tunnel kiln is unnecessarily expensive in installation and upkeep for low-priced product. Basis of different forms of the annular kiln is given.

The waste of fuel and the pollution of the atmosphere with smoke in the brick industry are notorious. The reasons for confining this subject to the firing of common brick are:

(1) The manufacture of common brick is the largest and the most essential part of the structural clay product industry, which includes also face brick, hollow building tile, roofing tile, terra cotta, drain tile and sewer pipe.

(2) Common brick is the cheapest clay product, and is sold for the lowest price per ton, not only of any clay product, but of any finished structural product.

(3) Because of the low price of common brick, the means of saving fuel in the firing of them, the fuel-saving kilns, must be quite different from what would be practical in other branches of the brick industry; they must not cost so much to construct that the interest on the increased investment, together with the up-keep, will amount to more than the saving of fuel, and thus add to the price at which the brick must be sold. "The economic and business world knows no waste, unless the saving can be accomplished at a profit."[2]

The means of saving fuel, however, in the firing of common brick are the same as that of any other clay product, as well as that in any ceramic or metallurgical operation, namely, regeneration and recuperation. The principle of regeneration was first applied to the firing of brick in Germany more than 60 years ago, the first practical kiln having been invented by Friedrich Hoffman in 1858. The Hoffman kiln, or some modification of it, has become almost universal in Europe and its use has spread all over the world. That it is not generally used in the United States is due chiefly to the wastefulness of America, which is proverbial, and to the fact that

[1] Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, February, 1925. (Heavy Clay Products Division.)

[2] "The Relativity of Waste," by Alfred Pierce Dennis.

in this country fuel has been abundant and cheap and labor high, so that our attention has been given to means of saving labor rather than saving fuel.

Another thing that has retarded the adoption of the continuous kiln in this country is that until recently the kilns of this character that have been built here have, for the most part, not been adapted to our conditions, having been imported or designed not by engineers or technical men, but by men who have perhaps worked on some plant in Europe and who have not understood some important feature or who, building a fairly good kiln, did not know how to operate it.

**Conditions Have Changed**

While labor is high, fuel has been much increased in price and, moreover, the Government, realizing that coal and oil are resources that are limited and are not now being formed, have inaugurated a policy of conservation, and we are all beginning to realize that it is our duty not to waste fuel.

The fully regenerative kiln is necessarily continuous in operation. Brick must be constantly firing, so that the hot gases passing through that part of the kiln under fire can be drawn through unfired brick, preheating them before escaping to stack; also so that there may always be burned brick back of the fire that, in cooling, heat the air for the combustion of the fuel. Hence, these kilns are generally known in this country as continuous kilns, the operations of setting, drawing and firing going on continuously in the same kiln. The original form of such a kiln was an annular tunnel in a round structure, with stack in the center, hence this kiln in Germany was called a "Ringofen." Continuous kilns are now generally oblong, the annular tunnel becoming two parallel tunnels connected at both ends, the ends being square, or a continuous tunnel, the ends being round, the smoke flue in both cases being between the two parallel tunnels. The tunnel is divided into chambers of a convenient size by means of paper partitions, to prevent back draft, there being a door in the outer wall at the end of each chamber through which the dried brick are taken for setting and the burned brick in drawing.

In another form of the continuous, progressing-fire tunnel kiln the parallel firing tunnels are separated by an open space that is utilized for taking the brick into the kiln, the outer side of tunnels having doors for taking out the burned brick. In some cases in this country there is only a single tunnel in a straight line. Such a kiln is not fully regenerative, since when it has been fired down the line to the end of the tunnel, the combustion gases must be wasted, as the distance is generally too great to utilize them for preheating the other end of the kiln, which must hence have starting furnaces, using cold air for combustion.

Another form of the continuous kiln is a series of parallel down-draft kilns in juxtaposition, the crowns resting on the partition walls between the

kilns. This is generally known as the compartment kiln. The progressing fire tunnel kiln may be divided into separate compartments also by permanent brick partitions, which form we designate a tandem-compartment kiln.

We must include also in the class of continuous kilns a form that is now being vigorously promoted, the railroad or car tunnel kiln, a long narrow tunnel with a track on which cars loaded with the products to be fired are mechanically and continuously or intermittently pushed through the tunnel from end to end, the fires being stationary and every cross-section of the kiln being kept constantly at a fixed temperature.

The problem then in the common brick industry is, which form of the continuous regenerative kiln is best for this low-priced product, since the only practical way of saving any great amount of fuel in the firing of common brick must be in making application of the regenerative principle of the continuous kiln.

The car tunnel kiln, properly constructed and operated, is undoubtedly the most economical in fuel, but it costs too much for installation and upkeep to be practical for common brick. Moreover, with clays that require time for oxidation, the car tunnel kiln must be operated on too slow a schedule, with too small an output. Also, for clays that have a high or sudden fire shrinkage most tunnel kilns are likely to give serious trouble from the brick on the outer courses of the car pulling over and rubbing against the sides of the tunnel or falling off and blocking the movement of the cars. Those who are promoting the tunnel kiln may argue otherwise, and with some reason. It would take too much time to discuss the question in this paper, so I shall dismiss it with the brief statement of my opinion that while the tunnel kiln will burn common brick, even better than in the present periodic kilns, yet another form of the continuous kiln, costing about half as much and saving nearly as much fuel, is more practical. It is not sufficient to get something better, but we must have the best, the most practical, the most economical kiln for every product.

The compartment continuous kiln can be adapted to the firing of any clay product, but it also involves too large an investment for the common brick manufacturer. An exception to this statement, with clays that will stand fairly rapid drying, so that the kiln-drying system can be used, is the open-top compartment kiln, fired with producer gas. The portable crown with cast iron frame is too costly. A simpler covering for the top is practical, making this kiln, with the automatic conveyors, one of the most economical systems of common brick manufacture. Such a system, as well as any continuous kiln system, should be designed and installed by an engineer of experience in this line.

The original form of continuous kiln, the progressing-fire tunnel kiln, known the world over as the Hoffman kiln, is the cheapest, simplest and

most practical kiln for the firing of common brick. The saving of fuel in this kiln is greater than in the compartment kiln and is almost as great as in the car tunnel kiln, and in some cases fully as great. There are many modifications of the Hoffman kiln, based on features described here.

### Method of Taking Combustion Gases from the Kiln

In one form of the Hoffman kiln the products of combustion are taken from the bottom of the tunnel, on one or both sides of the chamber, the outlets into the bottom of the smoke flue between the parallel tunnels being regulated by dampers operated on top of the smoke flue. In another form the products of combustion are taken out of the top of the tunnel in each successive chamber and conducted into the top of the smoke flue by portable pipes or sheet iron breechings.

There has been much discussion in conventions of brick manufacturers in Germany and in German journals of the clay industries as to which method of removing the combustion gases gives the better results. From these discussions by engineers and manufacturers I gather that both methods, when the kilns are properly designed for each and properly operated, are successful. In our own design of this kiln we have adopted the uptake method of removing smoke and combustion gases.

### Method of Watersmoking

There are many modifications of the Hoffman kiln based on different methods of watersmoking. It was early discovered that the original Hoffman kiln, watersmoked with the combustion gases after passing through four or five chambers of brick being preheated, produced scumming or discolorations. This objection to the new Ringofen was at first quite serious. It was investigated by Dr. Seger, who found that the gases from the coal and from the clay coming in contact with the cold, freshly set brick condensed on the brick, the water and sulphurous gases forming sulphuric acid which combined with the alkalis and alkaline earths of the clay and produced a scum on the surface of the brick, or discolored the edges. His diagnosis was accepted and his recommendation for preventing this has been in use ever since, namely the warming up of the freshly set chambers with air heated by cooling chambers. There are several patented features based on different methods of doing this.

A special watersmoking flue is generally constructed over the smoke flue, the damper rods of the draft valves extending up through this flue. Iron pipes or breechings connect the cooling chamber with the watersmoking flue and other iron pipes connect this flue with the chamber to be watersmoked, the heated air being drawn into the chamber by the natural or mechanical draft of the kiln through the regular draft valve. The

different methods of accomplishing this watersmoking are for the purpose of getting a better distribution of the heat throughout the chamber.

In no case is this perfect. Arrangements for better distribution are sometimes too complicated and costly to be practical. Perfection is not necessary, since completion of the watersmoking is not required to prevent discoloration of the brick, only the heating up of the chamber to a temperature high enough, about 150°F, to prevent condensation of the combustion gases.

In the Hoffman kiln with the up-take of combustion gases, the watersmoking or preliminary heating has been done by pulling outside air through one or more freshly set chambers the air being warmed by the heat stored in the kiln walls. In our form of top outlet there is a watersmoking flue underneath the smoke flue, and the heated air from the cooling chambers is pulled up through the chamber to be watersmoked.

## Method of Setting

The setting of the Hoffman kiln must be done right to get the best results. The manner of setting with different kinds of ware has been well worked out. It is not within the province of this paper to give instructions on this.

## Method of Firing

The Hoffman kiln is fired through small openings in the crown, the holes extending up through the filling and paving, with a cast iron frame in the top and a cast iron cover. The firing holes are properly spaced from long experience and a certain number of rows of holes are always being fired. Coal is not fired into a hole until the brick underneath are hot enough to burn the coal readily. The old method of firing such a kiln is with a small fire shovel such as is used in house-heating stoves. This method would be fairly efficient, if only a small amount of coal were put in at a time and the firing done often enough, except that too much heat might be lost by opening up the top too frequently, but this is practically unattainable, especially at night. The modern method is automatic firing with a practically steady stream of fine coal, only as much being fed as will be immediately consumed from top to bottom of kiln. This method gives more uniform burning and with less coal, estimated by German engineers at 20 to 30% less.

## Dimensions of Kiln

There are now well-established rules for proportioning the dimensions of the firing tunnel, draft outlets, main draft flue, stack, etc. In building a kiln today the engineer need not guess, but can calculate every dimension quite accurately.

## Draft

The Hoffman kiln, like all other continuous kilns, requires a strong draft for successful operation. It has been a most common mistake in the building of continuous kilns in America that the stacks have not had power enough and the firing has been too slow. This has now been remedied by the use of induced draft fans instead of stacks. With induced draft, moreover, the greater utilization of the heat of the combustion gases generally pays for the operation of the fan, and by the stronger and more constant and uniform draft the firing advance is more rapid. This more rapid advance of the fires also gives more heat from the cooling chambers for drying the brick.

## Drying Brick from Waste Heat of the Hoffman Kiln

There has been much discussion on the practicability of drying brick with the heat of the cooling chambers of a Hoffman kiln, some arguing that the only waste heat available is what can be utilized in drying racks over the kiln, an almost universal practice in Europe for many years. In recent years, however, with the more rapid firing with induced draft, heat is being drawn to tunnel driers on the yard level. There has always been more heat in the cooling compartments than is needed for heating the air for combustion, but with slow firing this was not available for use in drying in tunnel driers, since the pull of the waste heat fan interfered with the draft of the kiln or drew combustion gases into the drier, but with more rapid advance of the fires, the heat for drying is drawn back of open doors or so far from the fires as not to interfere with firing operations. Of course, there is not so much waste heat from continuous kilns as from periodic kilns, but it is entirely practical to get a portion of the heat for drying from this source, the amount depending upon the special form of continuous kiln and the rapidity of the firing.

## Fuel Consumption of the Hoffman Type of Kiln

There are many published records of fuel consumption in the Hoffman kilns in Europe. Where these reports are given in weight of coal per thousand brick, they are not of much use to us, unless we know the weight of the larger size brick made there and something of the thermal value of the coal, but where the results are given in per cent of the weight of the coal to the weight of the brick and the finishing temperature or cone is given, as is generally the case, we can get a fairly accurate knowledge of the economy of the kiln. Accurate, understandable records of fuel consumption in the Hoffman kilns in this country are scarce, as they are also in all types of kilns. I have recently had the privilege of seeing a number of Hoffman kilns in Nebraska and Missouri, firing common brick, face brick and hollow building tile, all hard, well-fired ware, at a low fuel cost,

unquestionably about one-third of what the consumption would be in periodic kilns. I also saw a Hoffman kiln at Salt Lake City which was turning out good common brick at a reported consumption of about 225 lbs. per thousand. The fuel consumption in these kilns could be lowered by automatic feeding of the coal and by pulling the combustion gases farther ahead of the fire by a stronger draft.

### Other Advantages of the Continuous Kiln

An advantage of the continuous kiln is that the plant is most compact, occupies the least ground space, is all under cover and can be operated in all kinds of weather. In other words it is a brickmaking factory, instead of a brickyard.

With automatic coal unloaders and conveyors and automatic stoking the labor of firing is reduced to the minimum.

Since the kiln is designed to be kept in constant operation the year around, chambers or compartments must, of course, be emptied as soon as fired and cooled, whether shipped immediately or not. Portable conveyors now make it practicable to place brick in stock without excessive cost. The interest on the working capital thus employed is far less than the overhead on an idle plant, and there is no safer investment than in good, well-made and well-burned brick.

Another advantage of the continuous kiln that is now receiving considerable attention especially where the brick plants are situated in cities, towns or villages, is that such kilns practically eliminate the smoke nuisance. The time is coming when no manufacturer will be permitted to pollute the atmosphere where people reside with the black smoke from the improper firing of bituminous coal.

### Conclusion

I have not expected to present anything that is new to most of the members of this Division, but feeling, strongly as I do, the duty of every brick manufacturer to conserve fuel and not needlessly waste it, especially when saving fuel so materially reduces the cost of his product, and knowing, as I do from many years' experience and observation and study, that the continuous, regenerative kiln, of an improved Hoffman type, is well adapted to the firing of common brick and hollow building tile, and is the most practical kiln for these products, I take this opportunity to urge you to investigate the merits of this system of firing, and when you are convinced, to use your influence to promote a more extended use in America of this fuel-saving kiln and thereby also bring into better repute brick as a structural material, by reducing the quantity of soft or salmon brick now produced to such an extent in the fuel-wasting up-draft kilns.

CERAMIC ENGINEERING CO.
COLUMBUS, OHIO

# THE VITREOUS SANITARY WARE INDUSTRY[1]

By W. A. Darrah

This discussion is intended as a summary of the vitreous sanitary ware industry, and a specific effort has been made to avoid a detailed technical discussion, in the belief that the basic facts will have a wider appeal than a technical discussion.

One of the objects of this paper is to point out that owing to the highly competitive conditions which now exist and which are rapidly becoming more marked, only those factories which are in position to manufacture ware with a high degree of economy and efficiency will be able to survive and show a profit.

The sanitary ware industry, like a great many of the allied clay products lines, is today passing from a condition of "rule-of-thumb" into a condition of highly practical, technical control of raw materials and manufacturing operations, including all steps up to the finished product. Without the proper control, competition will in the near future force plants operating by the rule-of-thumb out of business.

Vitreous sanitary ware in general includes such materials as bathroom fixtures, closets, tanks, lavatories, bathtubs, urinals, etc., kitchen sinks, washtubs, drinking fountains, bubblers, and a miscellaneous list of related equipment and fittings.

There are two classes of ceramic sanitary ware on the market in addition to the porcelain enameled iron ware, which has a definite field of its own. The first, *or better class of sanitary ware* is known as the "vitreous" ware, which is made from a white clay body, so compounded and fired at such temperatures that the material is dense, waterproof and vitreous throughout. This ware is of course glazed like all other sanitary ware, but the body of the ware is so dense that it has no appreciable absorption of moisture.

A standard, typical test for ware of this kind is the so-called "red ink test," which consists in spreading red ink over a broken portion of the ware and after allowing it to remain for five or ten minutes the ink is washed off. An examination of the ware will then indicate whether or not the ink has penetrated into the material. If no sign of penetration can be detected the test is satisfactory and the ware meets the requirements of the United States government and the municipalities and state regulations.

During times of competition much stress is laid upon the red ink tests, and all contracts sold to the United States government must satisfactorily pass this test. During normal conditions, however, very little attention is paid to this requirement providing the surface of the ware is dense, strong and well glazed. Even under conditions of considerable competition this

[1] Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, Feb., 1925. (White Ware Division.)

test is mainly applied to closets, and the other articles are frequently not subjected to a critical absorption test.

The second class of sanitary ware is the so-called "porcelain body" or "porcelain sanitary ware," which is non-vitreous, and usually has a yellow or buff color body beneath the glaze. The body is highly absorbent of moisture, but when properly made is so well protected by the glaze that the finished article will give highly satisfactory service. Ware of this kind is used very largely for such articles as bathtubs, large urinals, kitchen sinks, washtubs, etc. Lavatories are frequently manufactured from this kind of body, but closets and tanks are almost exclusively made from the vitreous ware.

The so-called porcelain body ware as a rule presents a less satisfactory appearance than the vitreous ware and normally commands a lower price. Aside from the cost of materials, the manufacturing cost of the porcelain body ware is substantially the same as the cost of the higher grade or vitreous ware, so that it is more profitable for the manufacturer to produce the highest quality ware, thus securing the best price for his product.

The present discussion will be confined entirely to the manufacture of vitreous sanitary ware.

**Relative Demand** Under normal conditions the principal products of the vitreous sanitary ware plant may be divided in approximately the following proportions among the various articles given in the table below.

| Article | Per cent of product |
|---|---|
| Closets | 40 |
| Tanks | 27 |
| Lavatories | 13 |
| Bubblers | 10 |
| Miscellaneous | 10 |

Local conditions will of course determine the relative number of articles produced, and, while it is not customary at most sanitary plants, too much stress cannot be laid upon the advisability of maintaining a relatively wide diversity of materials.

It is the writer's opinion from a careful study of the industry that the successful plants in the future will be those which maintain a relatively wide line of varying articles outside of the sanitary ware line.

## General Notes on the Manufacturing Process

The clay working industries date from the earliest records of civilization, and until relatively recent times this very old industry has escaped the modernizing influence of mechanical and scientific development. Many factors have been responsible for the lack of progress in the clay working industries, but prominent among these is the fact that the primitive

methods produce reasonably satisfactory results in times of slight competition, and without taking advantage of the most modern equipment very little improvement was possible. This condition is rapidly changing, and, as will be pointed out in this paper, the writer strongly believes that only those plants can survive which have complete control of their raw materials and processes and which use modern equipment throughout.

The older method of manufacturing sanitary ware consisted in pressing the clay, having the proper consistency, into molds of the form which it was desired to produce. After the drying, the clay ware was removed from the forms, dried, fired, glazed and made ready for shipment.

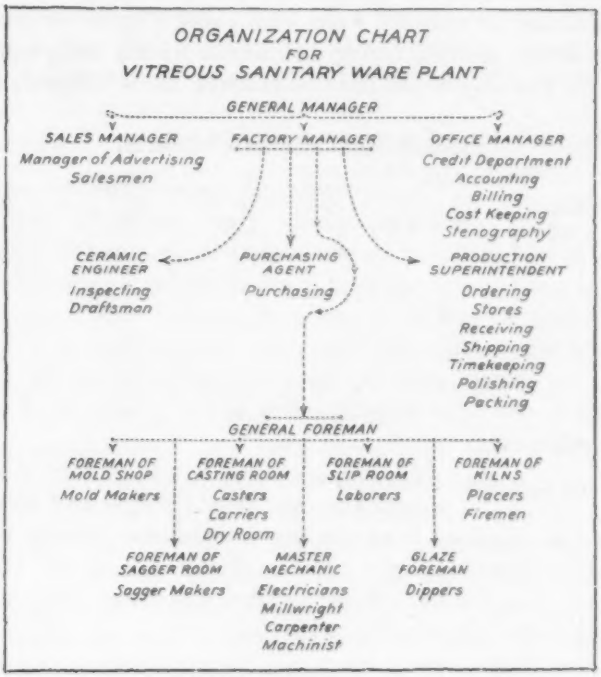


FIG. 1.

The above process, while relatively simple, is entirely dependent upon the skill and judgment of the workman, which has resulted in low output, attempted restriction of output by labor unions, increased costs and inferior quality of ware.

This discussion will ignore the above process (called "pressing") and will be confined entirely to the casting process, which, in the writer's opinion, is the only practical method to meet the quality and manufacturing costs demanded by present-day competition.

## Casting Process

While the casting process as applied to clay products has been known and used for a long time, the specific methods of casting sanitary ware are relatively new.

The casting process is of particular advantage because it gives absolute control of the raw material, a close control of the manufacturing operations, and an absolutely uniform product with a minimum amount of skilled labor.

These advantages will be brought out in greater detail in the following discussion.

The casting process is of course only a group of operations in the complete manufacture of sanitary ware, and Table I shows in summary the various distinctive manufacturing operations, tracing the progress of the ware from the raw clay to the finished material on the shipping floor.

## Steps in Handling Raw Material

**The Materials** The raw materials consist primarily of clay, flint, feldspar and the glaze materials, such as borax, silica, whiting and oxides of various materials, such as tin, lead, zinc, etc.

Clay, flint and feldspar are used in relatively large quantities, since the average slip may be said to be composed roughly of 50% clay, 25% flint and 25% feldspar. The above should not be considered as a working formula, as many factors must be taken into account, but the proportions mentioned will give a broad perspective of the quantities of the various materials employed.

**Raw Material Storage** To obtain the most satisfactory working conditions, the clay, flint, feldspar and related products, should be unloaded from the cars into suitable storage bins, which should preferably hold at least sixty days' working supply. Supplies of fire clay and material for making saggers and other refractory pieces, must also be stocked in working quantities.

Many of the higher grade clays may be purchased in a ground, pulverized condition, while the ball clay, and cheaper products are handled in the bulk or semi-raw state. A surprisingly large proportion of the clays used in the sanitary ware industry today are either imported from England or carried a long distance. While the cost of raw materials is not a large factor in the manufacture of this ware, there is at present considerable room for economy by the wider use of native clays in various localities. This involves some development but certainly no insurmountable problems.

The clays, flint and feldspar and other materials, are best collected from the bins by the sliphouse man in a scale car running along a narrow gage

track in front of the doors of the various bins. In the writer's opinion, a relatively intelligent man should be in charge of this process, as accuracy in scaling the various materials will well repay the expense involved, by maintaining uniformity and reducing losses in the various manufacturing operations and in the finished product.

**Weighing and Mixing** It is common practice to use an automatic scale car in which the weights are controlled by hooded levers so arranged that the workman is required to exercise no judgment, but merely care in counterbalancing each of the successive levers in the proper order. A scale car load ranges from 500 lbs. to 2000 lbs., depending on manufacturing conditions, but should preferably carry the complete manufacturing formula. After all of the levers have been counterbalanced by placing the proper amount of materials on the car, the car is wheeled to the elevator or conveyor and dumped. The elevator or conveyor delivers the materials to the blunger.

**Blunging** The blunging operation is one of considerable importance and must be allowed ample time to insure a thorough mixing of all of the materials and the production of a uniform, thin slip. Blungers for operations of this kind should preferably be free from exposed iron and either lined with tile or ceramic materials. Wooden linings may be employed but the depreciation and wear are quite rapid and the particles of the wood which are worn away of course enter the slip and occasionally cause trouble later in the manufacturing process. Blunging is continued for a period ranging from one to eight hours, depending on the nature of the raw materials employed. Four or five hours represents a common condition. In some exceptional cases a longer time is necessary. It is advisable to take all precautions to insure that no grease, oil or foreign materials enter the slip from the blunger or accessory machinery.

**Lawning** After the completion of the blunging period the slip is passed beneath an electro magnet and through a lawn, thus removing magnetic particles and lumps, pebbles, etc., which would of course be detrimental to the ware. A 120-mesh lawn is well suited for this preliminary step.

**Pressing and Reblunging** The slip after passing through the lawn is divided into two portions, one of which is returned to the slip blunger while the balance is passed to a filter press which reduces the moisture to 30 or 40%. The filter cakes from the press are then added in the proper proportion to the slip in the second blunger, together with the proper amount of electrolyte, and the mixture is blunged for the second time.

**Addition of Electrolytes** A number of materials are used for the electrolyte, but as a result of an extensive series of tests, it appears that a mixture of approximately equal

parts of sodium silicate and sodium carbonate give very satisfactory and quite uniform results. The amount of these combined materials will vary with the nature and character of the materials used in making the slip.

It has been developed by careful experimental work, that the hydrogen-ion content of the clay, as well as the fineness and chemical composition, very largely determine the quantity of electrolyte necessary. From 1/4 of 1% to 1/2 of 1% represents a common condition, and, as a rule, the proper quantities are determined by practical tests rather than on a theoretical basis.

**Storage of Slip**

After the completion of the second blunging, the slip, which contains from 25 to 30% water, is passed under a second magnet and through a second lawn which usually runs about 90-mesh to the inch. The slip is then stored in the slip tank where it is kept in continuous agitation until used.

The time of storage, temperature of storage and degree of agitation, frequently exercise a very remarkable effect upon the characteristics of the slip. It is, of course, essential that the storage slip be kept absolutely free from the addition of ground water, waste or other materials, as extremely small percentages of various chemicals may have a disastrous effect later on in the manufacturing process.

The slip when prepared for final use ordinarily runs from 25 to 35% of water, and has a density about equal to thick cream. Slip of this kind will ordinarily measure from 28 to 30 ounces per pint, although the viscosity of the slip temperature and measurement, and many other factors are of prime importance, besides the weight of the slip.

**Working Tanks**

From the slip tank the slip is pumped to the working tanks, which are normally located at a higher level than any of the rooms in which casting is being carried on. It is highly advisable that the working slip tanks be maintained at a uniform temperature and be not subjected to the varying conditions of weather.

For this reason slip tanks should normally be placed within the building, or if it is necessary to place them outside of the building or on the roof, they should be thoroughly enclosed and insulated against heat changes. If placed on the roof, or out of doors, proper provision for heating them should be made.

In all of the operations of handling the slip, the utmost care must be taken to maintain it clean and free from contamination at all times. Grease, splinters, particles of rubber, and materials of this nature, must be carefully avoided. Naturally particles of iron are extremely detrimental, as they will result in specks in the finished ware. Grease, wooden splinters, particles of rubber, and other forms of organic matter, frequently cause blisters, blowholes and related effects, some of which do not appear until the ware is fired for the second time.

**Slip Piping**

From the working slip tank the slip is distributed by means of slip pipes to the molding benches where it is drawn off into molds. In some plants the continuous circulation system is employed in place of working slip tanks. This system has certain advantages but also involves some rather marked objections, so that it is the writer's opinion that in most cases a working slip tank system is preferable to the continuous circulating system. There are occasionally conditions under which the above situation might be reversed, however.

All slip piping should be inclined at a definite angle and provided with connections for thoroughly cleaning and washing it out, preferably with steam or with compressed air.

## The Casting Process

The casting process of making sanitary ware is so simple and produces such consistently uniform results, that it is safe to predict that no other system of making ware of this class will be able to compete. Moreover, the great reduction in the necessity for skill and the elimination of the demand for trained men, has enabled the casting process to change the sanitary industry from one requiring skilled craftsmen to a commercial manufacturing business.

While, as previously stated, the casting of clay ware is not new, yet the manufacture of complicated shapes, such as those employed in the manufacture of closets for sanitary purposes, has resulted in the development of the hard body "over-casting," without which the sanitary industry would be seriously handicapped.

**Over-Casting**

The method of over-casting consists primarily in casting separately several individual portions of the finished article, assembling them in a master mold and uniting the entire assemblage by casting additional slip around the units.

**The Molds**

The steps in working out this process are clearly shown in the attached figures. Before passing to a discussion of the steps in casting, it may be pertinent to mention that the molds require some little attention and should be previously conditioned for moisture content before the casting operation proceeds. The mold which is too dry or the mold which is too wet will invariably cause trouble later on in the process. It is customary to dust the molds with pulverized dry body in order to reduce adhesion between the slip and the mold to a minimum. In casting, the mold should be filled evenly and accurately with the liquid slip, care being taken to avoid bubbles, drops of water or the inclusion of dirt.

**Casting of Closets**

Figure 2 clearly shows the step of assembling the base of the closet in the plaster mold. The base has been previously cast in a separate mold in another operation.

It is of course cast from the same slip and in the same manner as the other portions of the article are cast. The foot must have the proper moisture content, that is, it must be dried for a proper period before it can be safely used in a further casting operation.

Figure 3 shows the step of placing the trap on to the foot. The trap has likewise been cast in a separate operation, and when dried to the proper consistency is ready for use. Later views will show the molds for casting the foot and trap.

It will be noted that only ordinary care and skill are required in placing the trap on the foot, as shown in Fig. 3. No especial training is required and it has been found entirely feasible to take a new man, unfamiliar with

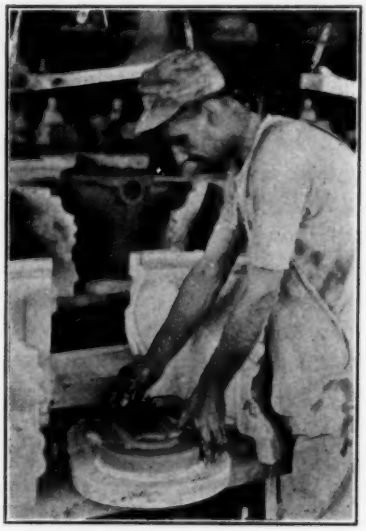

FIG. 2.—Placing foot in assembling mold.

FIG. 3.—Placing trap on foot.

pottery work. After giving him a training of two weeks he will be able to produce excellent ware. It is only necessary that the man have some inclination for mechanical work.

After the trap has been placed on the foot, as shown in Fig. 3, the main mold is assembled as shown in Fig. 4, including the trap and foot and providing spaces into which the additional slip later to be poured will run, uniting the whole combination into a single unit.

Inasmuch as the molds are duplicated from a set of master molds, and provided with proper spacing and locating notches, no skill or training is required for this step. After the two sides of the molds have been properly placed, as shown in Fig. 4, the top portion, which forms the depression

in the bowl, is set into place as shown in Fig. 5. The straps and clamps are next adjusted, holding all parts of the mold firmly in place during the casting process. It may be noted that the mold is not necessarily water tight, as any small leaks ordinarily promptly close themselves by the solidification of the slip.

When the mold has been assembled in the condition indicated in Fig. 5, the slip is poured either from a pail or flexible hose direct from the slip tank. As a further precaution it is advisable to pour through a screen or trap as shown in Fig. 6, as this removes any splinters, bits of organic matter, dirt, and even grease. The screen further serves the purpose of somewhat eliminating the rate of flow of the slip, and allows a better dis-

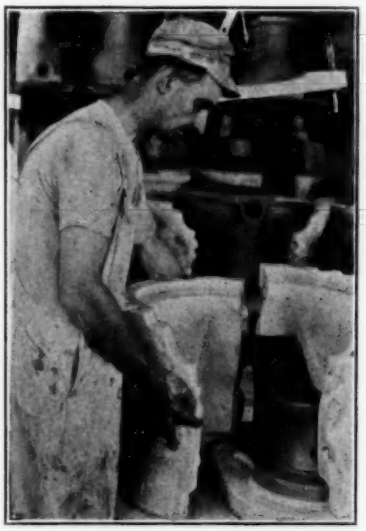

FIG. 4.—Putting mold together preparatory to casting bowl.

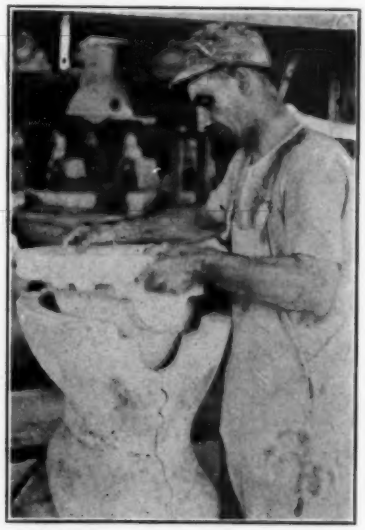

FIG. 5.—Putting on top of assembling mold.

tribution of the slip than could ordinarily be obtained by discharging directly from the slip hose. In some plants the screen or trap is not used in pouring, but as a rule, the greater uniformity thus obtained amply warrants the slight additional trouble and expense involved. It appears to be a principle in sanitary plants (as indeed in all other ceramic operations) that uniformity of material and treatment are absolutely essential to success.

After the mold has been poured it is allowed to stand for a period varying from two to four hours, depending upon the nature of the slip, condition of the mold and other factors. At the expiration of this time the slip is solidified sufficiently (due of course to the absorption of water by the

plaster) to permit of some handling of the clay body. The rim (which has previously been cast separately) is now placed on the top of the closet while still in the mold, and forced gently into close contact with the portion previously cast. In order to assist in a satisfactory union between these two parts, a roll of plastic body is ordinarily first placed upon the top of the closet previously cast.

The holes in the rim which distribute the water in the bowl are punched before the rim is pressed in place. Figure 7 shows this operation and the appearance of the rim before being placed on the closet. After the rim has been pressed into position the closet is completed as far as the casting and forming operation is concerned. It is allowed to stand in the mold for

FIG. 6.—Pouring the mold.

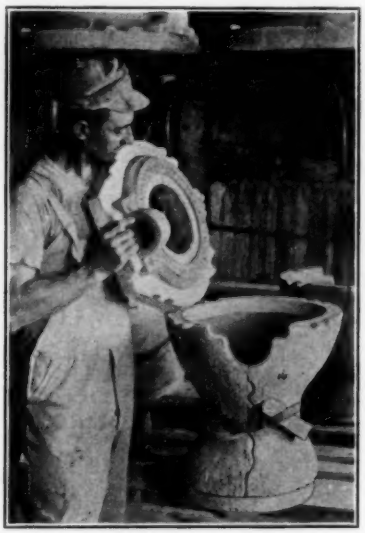

FIG. 7.—Putting rim on bowl in assembling mold—rim has been cast separately and punched.

a short additional period until it has reached a leather-hard state, at which time it is able to support its own weight without sagging, and has sufficient strength to permit trimming and smoothing seams, removing slight defects and placing it in final condition.

Proper judgment must be used as to the period that the closet is allowed to remain in the mold and the period that it is allowed to dry before the finishing and sponging operation. Inasmuch as the materials used are thoroughly standardized and the temperature and humidity conditions of the mold and atmosphere in the casting room are also thoroughly standardized, the drying time may be predicted very closely, thus again making

the operation merely one of manufacturing skill instead of requiring a highly trained operator.

Figure 8 shows above closet as it leaves the mold ready for preliminary trimming and drying.

**Casting of Tanks**

The casting of tanks is a somewhat similar operation, although owing to the relatively simple contour of the tank the operations are fewer.

Figure 9 shows the core of the tank being prepared for casting. The core, which is of course of plaster of Paris, must have the proper humidity conditions, and is ordinarily dusted with some of the dried, pulverized body before assembling.

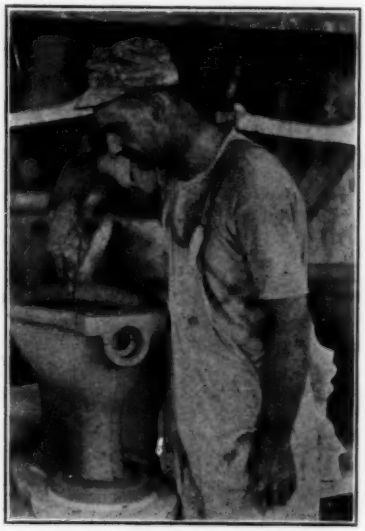

FIG. 8.—Bowl as it comes out of the mold ready for finishing.

FIG. 9.—Dusting core preparatory to assembling.

The sides of the mold are then placed upon the core, as shown in Fig. 10, after having been previously conditioned for humidity and dusted. When assembling, the mold is clamped and strapped in a firm manner in order to prevent displacement during operation.

The tanks, owing to their structure, can frequently be cast to advantage from the bottom, and can be poured slightly faster than is permissible in the case of forming the closets. The rising slip expands into two funnels at the top of the mold.

Figure 11 shows the operation of pouring the tank from the bottom. Funnels are used to maintain a proper head of slip above the upper portion of the tank. As in the case of casting closets, the tank is allowed to re-

main in the mold until it reaches proper consistency and is able to support itself. It will be evident that in all casting processes the core must be removed before the article being cast has dried sufficiently to cause shrinkage. Obviously, as drying and shrinkage take place, numerous cracks and defects will be caused if the cores are not promptly removed. Hollow corners sometimes result from this cause.

Figure 12 shows the tank removed from the mold.

The tank lids are cast in a separate mold, but after proper drying and finishing, are removed and pass through the final manufacturing steps in position on the top of the tank.

Figure 13 shows the lid mold being opened, and the lid inside.

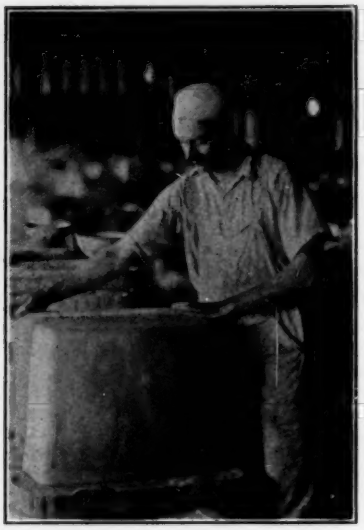

FIG. 10.—Assembling mold.

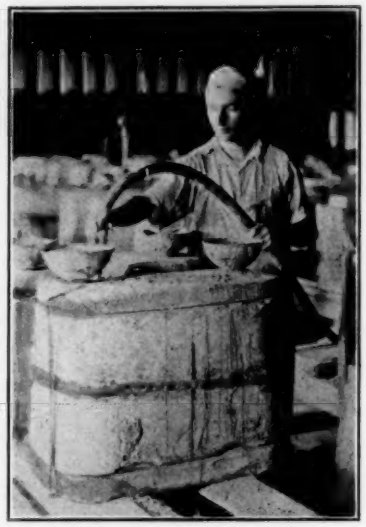

FIG. 11.—Pouring mold.

Figure 14 shows a general view in a casting room. In the left foreground will be noted a number of molds for casting tank lids. In the center of the picture is a workman clamping together a tank mold, while ware in other stages of manufacture will be noticed in other parts of the picture.

## Drying

The drying of ware of this class is of great importance. This fact has frequently been neglected, as it is of course possible to secure certain mediocre results by merely permitting the ware to dry in an open room or when stacked around the kiln. When dried in this manner it is not unusual for from four to ten days to elapse between the casting operation

and the first firing of the ware. Aside from the fact that an extremely large space must be reserved for ware when drying at this slow rate, it will be evident that a very large stock of ware must always be carried in a leather-hard condition, which means a considerable amount of money tied up, inasmuch as the labor of manufacture, the overhead and the cost of materials must be defrayed before manufacturing is begun.

It is entirely feasible to reduce the drying time for sanitary ware of this class in question to a matter of hours, when using driers equipped with proper humidity control. An actual drying period of eighteen hours is readily obtainable, with excellent results. Obviously, the chances for damage to the ware, as well as the handling, the storage required and the

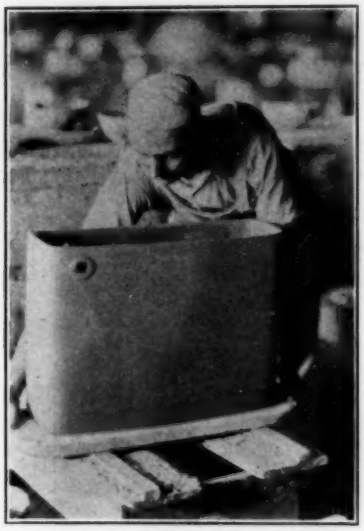

FIG. 12.—Tank as it comes out of the mold.

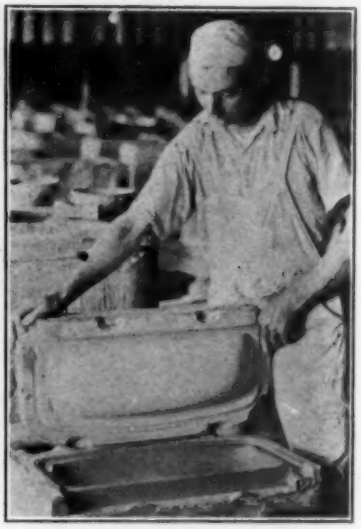

FIG. 13.—Opening lid mold showing cast lid.

capital tied up, are all proportionately reduced by a rapid drying. The drying cycle which has been found to give most satisfactory results, consists in subjecting the material to be dried to an atmosphere fully saturated with water vapor and maintained at a temperature close to 200°F. This condition is maintained until the ware is thoroughly heated through. After the ware is heated, the amount of moisture in the air is reduced, at the same time maintaining the wet bulb temperature constant. The result of this procedure is to avoid the formation of a case-hardening skin on the outside of the ware. The skin formed by surface drying would act to prevent further drying of the ware, or at least to greatly retard the rate of drying. On the other hand, by maintaining the humidity of the sur-

rounding air at the saturation point, there will be no appreciable transfer of moisture from the ware to the surrounding air during the heating period. On the other hand, at the conclusion of the heating period the temperature of the interior portions of the ware will be sufficiently high to force the moisture at these points to the surface, and the reduction in humidity of the surrounding air will then permit a transfer of moisture from the ware to the surrounding air.

A drier of this type consists primarily of an enclosed room, the walls of which are preferably well insulated, a blower of sufficient capacity to keep the air in the drying room in rapid circulation around all of the ware, and the necessary control devices and heating equipment.

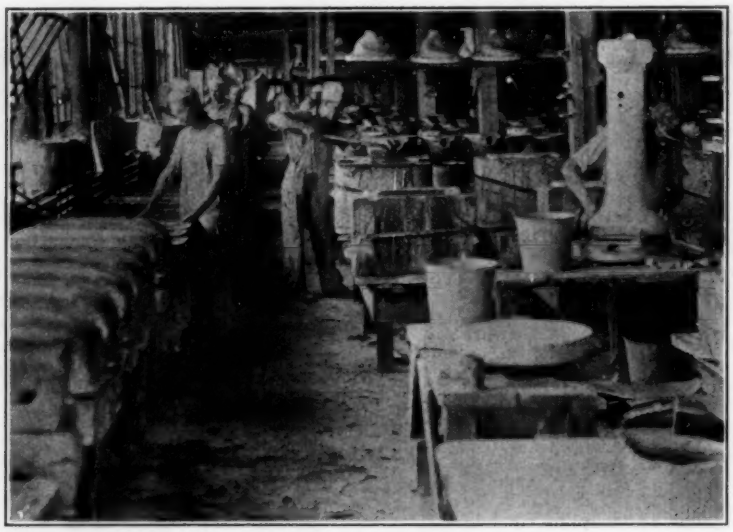

FIG. 14.

A drying room of this type is relatively inexpensive and extremely effective, and it is the writer's opinion that humidity drying along these lines must be installed by every plant in order to meet the keen competition of today.

The ware may be handled either on a system of automatic conveyors, on a series of skids and skid trucks, or it may be placed in the drier by hand and removed by hand. Local conditions will determine the most satisfactory driving mechanism for each individual case. The mechanism, however, should be relatively simple, and if it provides an inexpensive means of transporting the ware, the whole object is accomplished. In general, for the drying of ware as bulky as that here described, a system of skids and skid trucks will give very economical and satisfactory results.

**Finishing**

Drying in most plants may be divided into two stages, the first of which may be called the preliminary drying and the second the final drying. After the preliminary drying, which is commonly accomplished on racks or "stillage," the ware is given a final finishing, at which operation, irregularities, roughness, pinholes, etc., are removed as far as possible, by scraping or sanding. Some retouching with a wet sponge may be done at this time, although where possible scraping will give more satisfactory results from the standpoint of losses later on in the operation.

After finishing, the ware is placed in the dry room or returned to the stillage for the final drying.

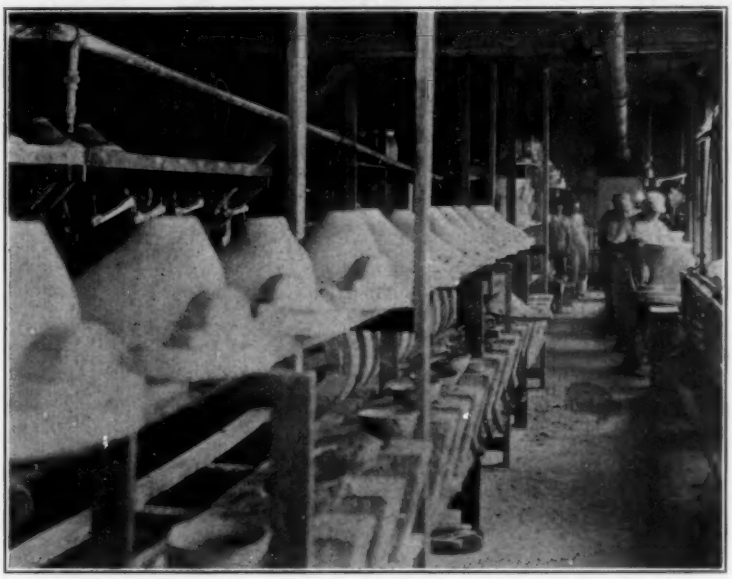

FIG. 15.

Figures 15 and 16 show some of the finishing operations.

**Final Drying**

The final drying, if carried on in the casting room, will require from one to two weeks, and under some conditions much longer before the ware is in condition to be placed in the kiln.

When dried in an automatic humidity drier, this operation may be completed on a 24-hour cycle and permit of a margin ranging from 4 to 6 hours for loading and unloading the drier. The humidity drier will therefore materially reduce the building space required for drying of ware in process of manufacture. The amount of saving of floor space by the humidity

drier may be calculated approximately on the assumption that ordinarily less than $^1/_{10}$ of the space occupied by the ware in drying will be required if a humidity drier is employed.

In all cases, however, the saving is not quite as large as might appear, for the reason that in a well-designed factory, the space above the casting benches is frequently utilized for stillage or drying of the ware.

An additional saving from the use of the humidity drier results from the reduced amount of ware in process of manufacture. For example, if a plant would normally produce 100 pieces of ware per day, which required 14 days for drying, there would obviously be approximately 1400 pieces of ware on hand between the initial casting and the initial firing operation.

FIG. 16.

On the other hand, if a humidity drier is employed there would be only slightly over one day's work, or approximately 100 pieces of ware. Assuming that the unfinished pieces represent an investment value of only $1.00 each, it will be apparent that $1400 will be continuously invested in unfinished ware without the drier, whereas only $100 would be invested where the drier was in use.

## Firing

The firing operation in the case of sanitary ware is one of the large items of expense, and where not properly controlled also involves possibilities of considerable loss.

The tunnel kiln, in the relatively near future will displace practically all other types of kilns for sanitary ware. Possible exceptions to this rather broad statement will of course develop due to special local conditions, special fuel costs, and other items. Inasmuch as the subject of tunnel kilns for pottery ware has been fully discussed in many excellent papers, the writer will not go into this subject in detail at this time. In a later portion of this paper, estimates of firing costs will be given and discussed. In passing, however, it is of interest to note that the tunnel kiln materially reduces fuel costs. In many cases where the same fuel is employed, the ratio is as great as 6 to 1 in favor of course of the tunnel kiln. In the same way the tunnel kiln materially reduces the labor costs, inasmuch as the ordinary round type of kilns require considerable skill in placing, in drawing and in firing. Placing and drawing, in the case of the tunnel kiln, become a matter of common labor, involving practically no skill. Firing in the case of the tunnel kiln is a matter of maintaining pyrometer readings at a constant figure, and therefore practically eliminates the necessity for personal skill required in the case of the periodic kilns.

FIG. 17.

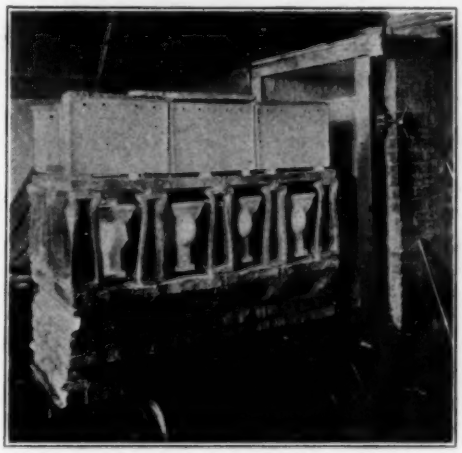

FIG. 18.

Figure 17 shows the interior of a typical periodic kiln in the process of being drawn. The laboriousness of the task is evident, and the pile of broken saggers, setters, etc., in the center of the floor, testifies to the mechanical breakage

involved. It will of course be evident also that the handling methods are extremely crude.

Figures 18, 19 and 20, show on the contrary, the operations of handling ware on tunnel kiln cars. The cars in question are used in a Dressler kiln but of course there are many satisfactory types of kilns upon the market.

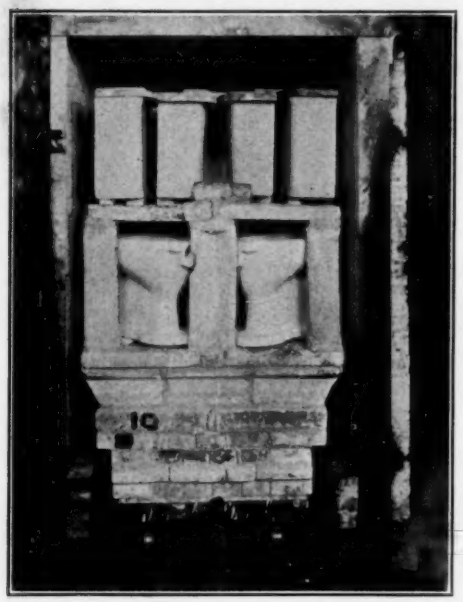

FIG. 19.

The firing cycle of sanitary ware is well known, and the limitations and restrictions to be observed have been fully discussed in previous papers. The upper limit for the bisque ware will usually run about cone 10, while glost ware may be fired as low as cone 6 or cone 8, depending on the exact formula used.

## Glazing

Most sanitary ware is now manufactured by the two-fire process, although certain experiments recently made indicate that sanitary ware can be satisfactorily manufactured with a single fire, applying the glaze on the green ware. Further development along this line will result in materially lower manufacturing costs, which, as previously mentioned is the crying need of the industry.

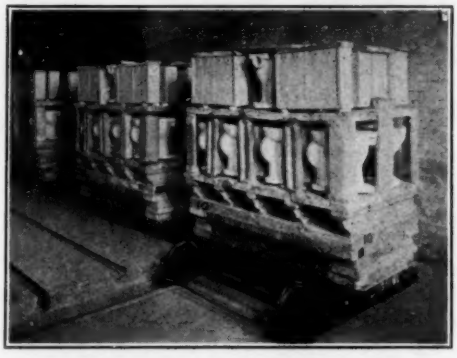

FIG. 20.

As is well known, the major difficulty in producing high grade sanitary ware in a single fire arises not so much from troubles in applying the glaze to the green ware as it does from the lack of opportunity to repair or retouch defective pieces. In other words, the loss in a single-fire process has normally been considerably higher than the loss in a two-fire process, and this has hitherto restricted the wider use of the single-fire

process in connection with sanitary ware, although some few manufacturers are now using the single-fire process.

The glazing of sanitary ware is applied in many plants by merely dipping the ware in large tanks of prepared glaze, as shown in Fig. 21. While the glazing operation appears very simple, considerable mechanical skill is required to insure the proper thickness of coat and a uniform application over the entire surface.

The weight and viscosity of the glaze are of fundamental importance in connection with securing a smooth uniform result. Glaze is frequently found to change its covering power and mechanical characteristics with age as well as with temperature. Such defects as jumping, cracking while drying, etc., occasionally result from this source.

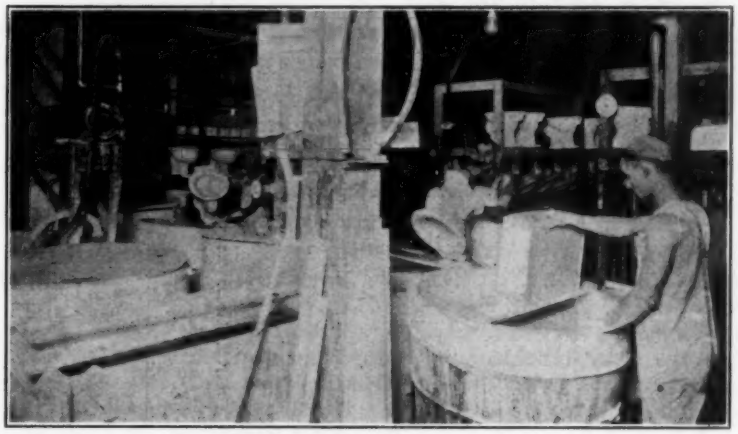

FIG. 21.

The bisque ware after having been dipped in glaze is dried on racks from 24 to 48 hours, depending on drying room conditions, after which it is placed in the glost kiln and fired.

The subsequent operations, such as unloading the glost kiln, inspecting, packing and shipping, involve few differences over ordinary white ware practice, and will not be further discussed.

### Organization Chart of Vitreous Sanitary Ware Plant

Figure 1 shows a typical organization plan for a fairly large sanitary ware factory. In many factories employing 200 men or less it is possible to reduce the number of executives by increasing the duties of the individual men. The organization shown on the enclosed chart would be ample for a production of 500 to 1000 pieces of sanitary ware per working day.

## Manufacturing Costs

The subject of manufacturing costs, in the opinion of the writer, is one of the most vital before the industry today, and success in reducing these costs to a minimum will determine which factors will survive and which will finally retire from the business.

It will be apparent that the detailed operations will vary widely in various plants, depending on mechanical equipment, skill of individual workmen, ability of executives, and other obvious factors. It is therefore obviously a dangerous expedient to specify an exact cost without surrounding the estimate with safeguards.

The enclosed Tables I and II should be considered with the above facts in mind, and are intended to be taken as representative of typical factory practice rather than of the first manufacturing conditions.

It will be apparent from a consideration of these tables, that a factory producing 500 pieces of sanitary ware per day would be involving a daily expense of approximately $2500, and this factor of course must be considered in connection with the financing operations necessary.

TABLE I

ANALYSIS OF ESTIMATED MANUFACTURING COSTS

Vitreous Closet Bowl with Spud—Packed for Shipment

(Weight 40 lbs.)

| | | | |
|---|---|---|---|
| Materials in bins | $0.42 | Dipping | $0.06 |
| Labor and expense of prepg. mat. ready for molds | .35 | Placing in biscuit kilns | .10 |
| Casting labor, including finishing | .90 | Firing glost | 1.21 |
| Carrying out | .03 | Inspecting | .03 |
| Drying | .06 | Packing (labor and material) | .20 |
| Placing in biscuit kilns | .10 | Mold depreciation | .06 |
| Firing biscuit | 1.02 | Sagger depreciation | .06 |
| Inspecting | .03 | Miscellaneous and overhead | .12 |
| Trimming (where necessary) | .05 | Spud | .19 |
| Total factory cost | | | $4.99 |

TABLE II

ANALYSIS OF ESTIMATED MANUFACTURING COSTS

Vitreous Tank with Cover—Packed for Shipment

(Weight 60 lbs.)

| | | | |
|---|---|---|---|
| Materials in bins | $0.65 | Trimming (where necessary) | .06 |
| Labor and expense of prepg. mat. for molds | .52 | Dipping | .06 |
| Casting labor, including finishing | .90 | Placing in glost kiln | .10 |
| Carrying out | .03 | Firing glost | 1.22 |
| Drying | .06 | Inspecting | .03 |
| Placing in biscuit kiln | .10 | Packing (labor and material) | .23 |
| Firing biscuit | 1.11 | Mold depreciation | .06 |
| Inspecting | .02 | Sagger depreciation | .06 |
| | | Miscellaneous overhead | .21 |
| Total factory cost | | | $5.42 |

## Investment Required

In order to get a picture of the sanitary ware business from the standpoint of the executive or business man, it is helpful to consider the factory equipment and investment in relation to the value of the product produced and the earning capacity.

Table III gives a summary of the factory departments involved in a sanitary ware plant, while Table IV gives a rough estimate of the investment in machinery and equipment for such a plant. It should be kept in mind that Table IV does not include any investment for buildings, kilns,

TABLE III

TABLE OF FACTORY DEPARTMENTS

| *A. Main Manufacturing Department* | *B. Auxiliary Shop Department* |
|---|---|
| 1. Slip room (including clay storage) | 1. Millwright shop (plumbing, sectional work, miscellaneous) |
| 2. Casting room | 2. Machine shop for repairs, etc. |
| 3. Drying room | 3. Glaze room for preparing glaze |
| 4. Inspection | 4. Glaze kiln for fritting glaze |
| 5. Firing or kiln room | 5. Carpenter shop for crating, etc. |
| 6. Dipping (or glazing room) | 6. Mold shop |
| 7. Packing room | 7. Laboratory (for anal., tests, control, development, etc.) |
| 8. Warehouse. | 8. Sagger shop |
| | 9. Stock room. |

TABLE IV

LIST OF MACHINERY REQUIREMENTS

For Manufacture of Vitreous Sanitary Ware (Capacity 25 Tons of Clay per Day)

| Item | No. required | Approx. total cost |
|---|---|---|
| Double blungers | 3 | $2520.00 |
| Lawns | 4 | 1800.00 |
| Slip pumps | 4 | 2400.00 |
| Filter presses | 2 | 2400.00 |
| Scale car | 2 | 1710.00 |
| Elevators | 3 | 1374.00 |
| Ball mills | 2 | 2400.00 |
| Dry pans | 2 | 3000.00 |
| Pug mill | 1 | 624.00 |
| Slip storage tanks | 2 | 2644.00 |
| Electro magnets | 4 | 1020.00 |
| Motor drives for above equipment | | 5260.00 |
| Machine shop equipment | | 4820.00 |
| Carpenter shop equipment | | 2832.00 |
| Millwright shop equipment | | 3820.00 |
| Miscellaneous shovels, pails, scales, lawns, etc. | | 2600.00 |
| Installation, labor and material | | 6148.00 |
| Total | | $47,372.00 |

or other equipment, which figures are given in Table V, except land and building.

TABLE V

LIST OF AUXILIARY SHOP EQUIPMENT FOR MANUFACTURE OF VITREOUS SANITARY WARE

| Item | No. required | Approx. total cost |
|---|---|---|
| Drier (controlled humidity) | 3 | $7,350.00 |
| Frit kilns | 2 | 2,080.00 |
| Service kilns | 1 | 3,800.00 |
| Tunnel kilns (2 for biscuit, 1 for glost) | | 350,000.00 |
| Distributing slip tanks | 6 | |
| Clay storage bins | 10 | 8,500.00 |
| Piping, fittings, etc. | | |
| Narrow gage track | 600 ft. | 1,240.00 |
| Work benches | | 8,235.00 |
| Racks | | 5,768.00 |
| Miscellaneous tanks | | 4,200.00 |
| Jigs and fixtures | | 12,000.00 |
| Molds | | 32,000.00 |
| Laboratory and equipment | | 10,000.00 |
| Automobile trucks | 2 | 7,600.00 |
| Miscellaneous | | 18,000.00 |
| Total | | $470,773.00 |

TABLE VI

SUMMARY OF ESTIMATED TOTAL ULTIMATE INVESTMENT

| Item | Amount |
|---|---|
| Shop auxiliary equipment | $120,773.00 |
| Kilns | 350,000.00 |
| Machinery | 47,372.00 |
| Real estate (four acres) | 100,000.00 |
| Buildings | 154,000.00 |
| Miscellaneous | 15,000.00 |
| Total fixed investment | $787,145.00 |
| Liquid capital requirements | 200,000.00 |
| | $987,145.00 |

In addition to the investment in fixed capital, shown in Tables IV and V, an investment in liquid capital must of course be considered. Such an investment will naturally depend upon the rate of turnover and size of operations. In the case of a plant having a capacity of 1000 pieces of sanitary ware per day, in the neighborhood of $200,000 liquid capital would be required. The total capital requirements then of such a plant are shown on Table VI.

## Earning Capacity

The earning capacity of a sanitary ware plant is naturally largely dependent upon the market price for the product, the efficiency of operation, and many other variable factors which go to make up the total business hazard.

Naturally the sanitary ware business has prospered immensely in the years of large building activity, and conversely, it has suffered serious loss during periods of business depression.

Looking over the records of twenty-five typical sanitary ware plants in the United States for a period of years, the results show average earnings in excess of 10%, and in some years, earnings which in individual cases appear to approach 50% of the total investment.

The future of the sanitary ware business appears to be very bright, although there will undoubtedly be extremely keen competition, which will mean that the well organized, well managed companies will prosper, while some of the weaker and less efficiently organized companies will undoubtedly cease operations.

THE CONTINENTAL INDUSTRIAL ENGINEERS
CHICAGO, ILLINOIS

NOTE: The writer wishes to acknowledge the courtesy of the Universal Sanitary Manufacturing Company in permitting the use of the above photographs.

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## RESEARCH RESULTS APPLIED TO THE PLANT. WHY, WHEN, AND HOW[1]

BY MARION W. BLAIR

A clay plant poorly managed, with unknown costs, obsolete and wasteful methods and equipment, has become to my mind an economic menace. I regard it in the same light as I regard a possible fire, explosion, or any other preventable disaster and as much of a personal menace as is a rattlesnake or a copperhead—but I see more of plants than snakes, so if in this paper any statements seem to be more severe than necessary, this attitude of mind which I cannot avoid is my apology, and possibly explains why I continue to hammer along the same lines.

This paper is written and presented with the very definite object of provoking a discussion of the points involved, but if the distribution and assimilation is as slow in proportion to its importance as the published results of the recent kiln firing investigation most of the debating will be done by the next generation. I carried in my grip a copy of the report in question for six months before I even found a copy in any plant and never have I seen a published comment on the work which included information as to where and how a copy might be obtained. Later, such discussion as I have heard has led me to believe there is not a clear enough understanding in the industry as to what may or may not be considered research work and not a clear enough understanding as to the application of research results.

[1] Presented at the Annual Meeting, Columbus, Ohio, Feb., 1925. (Heavy Clay Products Division.)

Research is primarily the effort to establish facts or principles by careful seeking and study. The emphasis in this definition should be put upon the words *effort, seeking* and *study*. The clay industry does not seem to realize there can and must be a great deal of pure research without actually establishing anything as a fact, much less pointing out a definite application or making an immediate financial return, and it is not in the fact itself but in its application that the profit lies.

From the application of certain basic principles has been developed the whole electrical industry. But the facts disclosed by Faraday were regarded with idle curiosity for more than half a century and the so-called practical men said, "yes all very interesting but of what value." But the modern generator and motor are designed along lines laid down by the first experimenters and there now seems to be no limit to their practical usefulness.

It may or may not be fortunate, but facts are facts, mechanical laws may not be broken without disaster and there is no chance to bootleg where a chemical reaction is concerned. For instance, there is a limit to reducing the fuel consumed in drying or firing clay wares, a limit to the efficiency of apparatus in use, but in seeking to reach these limits the plant operator will spend a useless amount of money unless he knows in advance how far he may reasonably expect to go. It is in my opinion the province of the research worker to establish such limits as indisputable facts. With each step toward the limit, however, as disclosed by work already done it is possible to improve conditions and the application should be made immediately to existing apparatus. The recent kiln firing investigation disclosed the fact that many plants are firing certain typical materials in typical kilns with a definite amount of coal per ton of clay and a certain length of time—a condition which if it existed in all plants of that particular type would mean an unbelievable saving in cost. Therefore, the time is here to apply results that far. The first step for any plant in an attempt to make application of such information to its own operation would be to determine and make a record of its past or present practice. It is a fact that many plants do not even weigh their coal, a small percentage do, yet such weighing is profitable if only to check the coal actually received against the tonnage paid for. But is it necessary for a laboratory car to camp on a plant to weigh coal? So far as that plant is concerned the establishment of the actual amount of coal used would be the result of research and the determination of the amount used per ton of ware would be the application of that research to plant operation. If a reduction can be made then the research begins to pay a profit. The careful comparison over a period of time with the amount consumed in other plants as disclosed by published research would be a step toward the application to the plant in question. If the amount is found to be

below the average then that plant may have some information on firing which would be of benefit to the industry as a whole, but if it is more, then there is a very definite objective in following up the methods of control as disclosed by the research in question. The same method may be employed as to any other plant operation which has been made the subject of study or comparison.

The starting point is a record of present plant practice, which can only be made by the use of definite controlling apparatus, the simplest of which is a platform scale, and which can be extended to include recording pyrometers and thermometers and draft gages on through the equipment of a modern laboratory. But the amount of profitable apparatus is limited by the personnel of the plant organization and its ability to intelligently use such equipment or its capacity to receive and benefit by instruction in its use. The use of a pyrometer for the sole purpose of recording the sleeping time of the night firemen is a silly yet common conception of its use. One might just as well give the night watchman a lantern and lock it in the office for fear he will break the globe.

I have made the specific item of coal consumption the subject of this paper and have referred to the work of research on kiln firing because that item still looms large in excessive cost and as a worthy point of attack, but other departments are, of course, subject to the same procedure and the application of any research result may be determined by a study of existent conditions and an intelligent comparison with known or published facts.

There is, however, a confusion between research and engineering construction and between the result of the research itself and the application of the facts established. For instance, on the subject of material handling I would scarcely call the substitution of a planer for a steam shovel or the use of a drag line rig instead of team and scraper research—and yet suggestions through the press as to research to be undertaken would seem to warrant the belief that individual plant operators would impose the selection of such equipment for them on a bureau supported from a general fund and call it research.

You who are here may ask why I take up your time with such criticism and please remember, criticism may be friendly and commendatory as well as otherwise, you may all feel you have passed the stage where you need to discuss such elementary subjects, but if there happens to be here for the first time the representative or if in the printed page these remarks are read by the representative of such plants as I have seen and investigated the past year, and the effect is either to cause him to wake up or drop dead of shame I shall have been repaid.

I shall describe one or two and then I am done—

A plant in Michigan, producing 30 M brick per day of shale, situated

in a face brick market, allowing 25% to 30% of its output to go into 2nd and 3rd grade material from scum and rough handling, consuming nearly a month's time to turn each kiln, using a booster furnace to help out a waste heat drier, setting wet brick nearly half the time, consuming 2000 pounds of $6.00 coal per 1000 bricks, never used a pound of barium, never used forced draft in any form, and never made a real dollar. Such a plant and such operation is surely a menace to the entire industry and it cannot be considered in any other light.

A plant in Indiana with 16 good kilns and 19 tracks of drier, producing 52 M brick of indifferent quality used for face brick, production said to be limited by the drier, admitted to consumption of 1600 pounds of coal per 1000 bricks, kilns on fire for eight and nine days, would like to increase production but does not believe it can be done, not a thermometer or pyrometer on the place, cool their ware through the drier irrespective of requirements, and sell their output below all competition.

I leave for you to determine whether such plants need research or application of established facts, and whether or not your business is vitally affected by such apparent and gross mismanagement and lack of information.

St. Louis, Mo.

# ACTIVITIES OF THE SOCIETY

## ROSS C. PURDY RESIGNS AS SECRETARY OF THE AMERICAN CERAMIC SOCIETY

The Board of Trustees regrets to inform the members of the SOCIETY that Mr. Ross C. Purdy has announced his wish to discontinue as secretary of the SOCIETY on March 1, 1926.

The Board has been loath to grant this request and the members of the SOCIETY will be disappointed to learn that our secretary has found it necessary to give up the office in which he is serving the SOCIETY so well. This announcement is not, however, intended to serve as a tribute to the splendid work rendered by Mr. Purdy, who will continue as secretary of the SOCIETY during the remainder of his term. When he leaves the office, he has promised to be as active in constructive service to the SOCIETY as in the past.

A successor has not yet been appointed. The Board invites the coöperation of the SOCIETY in selecting a worthy successor of Mr. Purdy.

E. WARD TILLOTSON, President.

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## SUMMER MEETING, IN CANADA, JULY 4–11 INCLUSIVE, 1925

The summer meeting of the AMERICAN CERAMIC SOCIETY will be held this year from July 4 to 11 inclusive. The following schedule will be followed during this trip:

July 4—(Sat.)—Leave Rochester, N. Y. for night boat ride across Lake Ontario to Kingston.

July 5—(Sun.)—Day ride down St. Lawrence River through the rapids and Thousand Islands to Montreal. Re-embark immediately for night ride on the St. Lawrence to Quebec.

July 6—(Mon.)—In and about Quebec.

July 7 and 8.—(Tues. and Wed.)—Ceramic Mines and Plants south of St. Lawrence—Thetford, Sherbrooke, St. Johns and Montreal.

July 9 and 10—(Thurs. and Fri.)—In and about Toronto.

July 11—(Sat.)—Niagara Falls or Hamilton.

The Canadian Department of Mines, The Canadian National Clay Products Association and The University of Toronto are making detail itinerary and meeting plans, announcements of which will be made as they develop. Additional optional plans will be made for those who wish to spend more time in Canada.

The important thing is for you to mark July 4 to 11 inclusive on your calendar as a week of exceptional recreational and informational opportunity with fellow ceramists from all parts of the continent.

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## NEW MEMBERS RECEIVED FROM APRIL 15 TO MAY 15

PERSONAL

**Alan I. Appelbaum,** 333 Ardmore Ave., Trenton, N. J. President, International Products Corp.

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NOTE: The SOCIETY is putting on a vigorous membership campaign during the month of June. Every ceramist should have the *Journal* and should be identified with this organization. Application cards will be sent on request.

**Asher Atkinson, Jr.,** 49 Mine St., New Brunswick, N. J. Student.
**Henry J. Cunningham,** 91 Central Ave., Glen Rock, N. J. Student.
**Walter B. Ebert,** California Clay Products Co., South Gate, Calif. General Superintendent.
**D. L. Gillett,** Westfield Clay Products Co., Westfield, Mass. Treasurer.
**Clinton R. Kennaday,** D. U. House, New Brunswick, N. J. Student.
**Roy Miller,** 484 Kent St., Sydney, N. S. W., Australia. Representing Carborundum Co.
**Bernard Moore,** Stoke-on-Trent, England.
**A. B. Morse,** 3807 Brunswick Ave., Los Angeles, Calif.
**William M. Myers,** Bureau of Mines, New Brunswick, N. J. Associate Mineral Technologist.
**Stuart M. Phelps,** Mellon Institute, Pittsburgh, Pa.
**Rodney T. Rouse,** 164 College Ave., New Brunswick, N. J. Student.
**Harold B. Sparks,** Nashville Pottery Co., Nashville, Tenn. General Manager and Secretary.
**Martin H. Thornberry,** Box 608, Rolla, Mo. Associate Professor of Metallurgical Research.
**Wilbur R. Wyckoff,** Hertzog Hall, New Brunswick, N. J. Student.

CORPORATIONS

**Clay Products Association,** 913 Chamber of Commerce Bldg., Chicago, Ill. Geo. D. Lenth.
**The Inland Fire Brick Co.,** 1252 E. 55th St., Cleveland, Ohio. Geo. S. Davies, President and Treasurer.
**The Laclede Gas Light Co.,** Olive at 11th St., St. Louis, Mo. W. H. Whitton, Vice-President and Secretary.

## Membership Workers' Record

| | Personal | Corporation |
|---|---|---|
| Harry E. Davis | 1 | |
| Charles F. Geiger | 1 | |
| L. C. Hewitt | 1 | |
| H. A. Huisken | 1 | |
| C. J. Kirk | 1 | |
| W. L. Shearer | 5 | |
| E. Ward Tillotson | 1 | |
| Edward J. Vachuska | 1 | |
| Albert S. Walden | | 1 |
| Office | 3 | 2 |
| | 15 | 3 |

## PERSONAL NOTES

**M. L. Bell** of the General Refractories Co. has been transferred from the plant at Danville, Ill. to Altoona, Pa.

**R. R. Danielson** of the A. J. Lindemann and Hoverson Co., of Milwaukee, Wis., delivered three lectures before the students in the Dept. of Ceramic Engineering, Univ. of Illinois, May 1 and 2. The talks were on "The Enamel Industry," and "Preparation and Properties of Enamels."

**George P. Fackt,** formerly General Manager of the Denver Terra Cotta Co., Denver, Colo., is now located with the Northwestern Terra Cotta Co., 2525 Clybourn Ave., Chicago, Ill.

**Miss Mabel C. Farren** of Pittsburgh, and formerly Secretary of the Art Division of the SOCIETY, is situated at Monmouth, Oregon, at the State Normal School.

**J. Ellis Harvey** has moved from Ridgway, Pa., to St. Petersburg, Florida, Box 1778.

**Geo. F. Hersey** writes that his address now is Suite 601, Western Mutual Life Bldg., Los Angeles, Calif. Mr. Hersey moved from Akron, Ohio.

**Gordon Klein** has recently taken a position with the New Castle Refractories Co., New Castle, Pa. Mr. Klein moved from Springfield, Ill., where he was employed by the Springfield Paving Brick Co.

**G. W. Rathjens** of Evanston, Ill. is now living in Fairbanks, Alaska.

**Charles F. Ryan** has recently resigned from the Russell Engineering Co., St. Louis, Mo., and is associated with the Thatcher Mfg. Co., Elmira, N. Y.

**George R. Shelton, Ph.D.,** Univ. of Illinois, who has been teaching ceramics at the University of Saskatchewan, was recently appointed as Assistant Professor of Ceramic Engineering at North Carolina State College, Raleigh, N. C.

**R. R. Shively,** Chief Technologist of the B. F. Drakenfeld & Co., Inc., was recently made a director in the same firm.

**L. G. Wassman** of Chicago has affiliated himself with the Pacific Sanitary Mfg. Co., and is living at Richmond, Calif.

**Prof. W. G. Worcester** of the University of Saskatchewan sailed on May 2 for points in England, Holland, Germany, Czechoslovakia and France in the interests of the Lignite Utilization Board of Canada and the Bureau of Labor and Industries of the Canadian Government.

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## LOCAL SECTION MEETINGS

### Pacific-Northwest Summer Meeting

Members of the three Associations of the Pacific-Northwest, *i. e.*, the Local Section of the AMERICAN CERAMIC SOCIETY, The Clayworkers' Association and the Brick Manufacturers' Association will hold their Summer Meeting on June 20, 1925, at Portland, Oregon.

A tentative program has been planned with the following addresses:

1. "Terra Cotta Roof Tile," by David R. Hood.
2. "Latest Improvements in Plant Construction," by Samuel Geijsbeek.
3. Ralph P. Stoddard, Secretary of the Common Brick Manufacturers' Association of America is coming from Cleveland, Ohio, with an important message.
4. "Soluble Salts in the Manufacture of Terra Cotta and Slip Coatings for Brick Work," by A. L. Bennett.
5. "The Value of Research in the Clay Plant," by Wallace Thoreson.
6. "What Kind of Ceramic Education Do We Want at the University of Washington," by Hewitt Wilson.

Members are especially urged to be in Portland during the week of the meeting because the Portland Rose Festival will make an added attraction during the same week.

Trips will be made through clay factories and an outdoor meeting and picnic up the Columbia River Valley.

## Detroit Section

Dr. E. Ward Tillotson, President of the AMERICAN CERAMIC SOCIETY, was speaker at a meeting of the Detroit Section, April 30, 1925. The subject of his address was "Research in Refractories and Important Applications."

Following dinner and Dr. Tillotson's address, a business session was held and plans outlined for meetings next fall.

Sixty-five persons were present and many large corporations of the vicinity were represented.

## St. Louis Section[1]

On May 13, the St. Louis Section of the AMERICAN CERAMIC SOCIETY had a dinner meeting at 7.00 P.M. at the St. Louis City Club and had as its chief guest, Ross C. Purdy, General Secretary of the SOCIETY; also invited guests, namely, Dr. Walter E. McCourt, Dean of Engineering; Prof. G. Ferrand, Head of School of Architecture, and Prof. Wuerpel, Head of School of Fine Arts, all of Washington University, St. Louis. Forty-seven were present at the dinner and fifty-one at the meeting which followed. Twenty members of the St. Louis Enamelers' Club attended.

The meeting was most enthusiastic, due to Mr. Purdy's presence. The evening was devoted to a general discussion of the question of a Ceramic Course; also a Research and Testing Laboratory at Washington University, enabling the local manufacturers of Ceramic Products to have their products tested and Research undertaken. It would seem most desirable to have a course in Ceramics and a Research and Testing Laboratory established at Washington University in St. Louis, where practically all types of ceramic industries are located. Mr. Purdy pointed out the fact, that at present there is a demand for twice as many Ceramic Engineers as are available from the present existing schools.

A Committee to investigate the requirements of the ceramic manufacturers with reference to a Research and Testing Laboratory was appointed with a view to directing their attention to the splendid equipment and facilities at Washington University; on what basis it could be utilized and other equipment added as required, including also the question of a Ceramic Course for day and evening classes.

Following is the Committee appointed by the Chairman:

Messrs. Chas. W. Berry, George Thomas, Frank G. Jaeger, Jacob Stocke, F. Holmes and L. C. Hewitt.

Frederick E. Bausch, Chairman, presided.

Those who attended the meeting were as follows:

Frederick E. Bausch; Ross C. Purdy, AMERICAN CERAMIC SOCIETY; L. C. Hewitt, Laclede-Christy Clay Products Co.; E. H. Wuerpel, St. Louis School of Fine Arts, Washington University; W. H. Weber, Roxana Petroleum Corp.; H. W. Weber, Russell Engineering Co.; J. L. Crawford, Laclede-Christy Clay Products Co.; Wm. W. Aulepp, Russell Engineering Co.; James Cox, Russell Engineering Co.; H. D. Cushman, The Ferro Enameling Co.; F. G. Jaeger, Superior Enamel Products Co.; A. H. Sullivan; P. J. McCullough, Scullin Steel Co.; Frank L. Kehl, The Brilliant Co.; J. Koeber, Wrought Iron Range Co.; Harry Grospoeler, Wrought Iron Range Co.; C. W. Berry, Mitchell Clay Mfg. Co.; Fred Talbot, Laclede-Christy Clay Products Co.; Clayton S. Haupt, Wrought Iron Range Co.; Marie Reginer, Silica Enamel Sign Co.; E. A. Eigenbrot, Buck Stove and Range Co.; John J. Lawler, Allied Industrial Products Co.; John Hartman, Karr Range Co.; Jack A. Rumer, Ferro Enamel Supply Co.; E. O.

[1] L. C. Hewitt, Secretary.

McFadon, Karr Range Co.; F. S. Markert, Belleville Enameling and Stamping Co.; W. B. Halley, Buck Stove and Range Co.; Julius A. Kayser, Laclede-Christy Clay Products Co.; W. F. Godejohn, Laclede-Christy Clay Products Co.; Henry W. Perry, Laclede-Christy Clay Products Co.; F. J. Stretch, Koken Company; P. Buettner, Porcelain Enamel and Manufacturing Co.; Foster Holmes, Evens and Howard; B. W. Willson, Evens and Howard; Y. R. Anderson, Evens and Howard; J. D. Robertson, Robert W. Hunt Co.; Wm. D. Thompson, Laclede Gas Company; H. B. Holman, Laclede Gas Company; T. E. Wood, Laclede Gas Company; H. E. Weightman; H. V. Farr, Mallinckrodt Chemical Works; A. E. Hug, Roesch Enamel Range Co.; Henry Oesterle, Roesch Enamel Range Co.; Bernard Enter, Buck Stove and Range Co.; Frank G. Roberts, Porcelain Enamel and Mfg. Co.; Gabriel Ferrand, Washington University; W. E. McCourt, Washington University; Fred Schwetye, Missouri Fire Brick Co.; Geo. Thomas, Highlands Fire Brick Co.; Mr. Gosrean; Mr. Stocke.

### Pittsburgh Local Section Meeting

The Pittsburgh Section of the AMERICAN CERAMIC SOCIETY held its annual election of officers last Friday evening in the Mellon Institute, at which the following officers were elected to serve for the current year: Chairman, E. J. Casselman; Vice-chairman, C. E. Nesbitt; Secretary, Foster Robertson; Treasurer, H. A. Willetts; Councillor, Francis Walker, Sr.

The election was followed by a paper by the retiring chairman, J. W. Cruikshank, who talked on the plate glass industry, tracing the progress which has been made and culminating with the present conditions of that industry. A diagram was shown giving the production and consumption of plate glass from 1885 to the present time. Mr. Cruikshank showed a number of lantern slides of factory views and equipment, showing old casting kilns and various methods used in former years.

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## CHAIRMAN OF MEMBERSHIP COMMITTEE APPOINTED

President Tillotson has announced that R. R. Shively of the B. F. Drakenfeld & Co., Washington, Pa., has been appointed Chairman of the Membership Committee of the SOCIETY. A list of the members of this Committee was published in the May *Bulletin*.

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## IN MEMORIAM

### Richard R. Hice

Richard R. Hice unselfishly contributed several years of his life to the gathering and making public records of exact information about the ceramic materials of Pennsylvania. His business was the manufacture of face brick. He was well informed, practically, concerning the manufacture of clay products generally. His knowledge of geology, particularly of Pennsylvania, resulted in his appointment over a term of several years as State Geologist. His broad and fundamentally sound ceramic knowledge coupled with his generous desire to share with others brought to him the highest possible positions of honor and service in several societies.

Expressions of personal appreciation were not withheld from him while he was yet active. If opportunity were given our pages would be filled with many expressions such as are here given. These are from his associates with whom he labored so faithfully and successfully from the earliest for this SOCIETY.—EDITOR.

The announcement of the death of Richard R. Hice comes as a great shock. One by one we are passing on.

Hice was present at our first meeting at Columbus in 1899. I have a picture of a group of seven taken on the steps of Orton Hall. Hice is one of them. I also have his signature as president on the charter granted to the student branch here in 1915.

He was a man widely informed in the field of geology which he had chosen and yet he was unassuming. I always enjoyed his genial disposition. CHAS. F. BINNS

The departure of Richard R. Hice, one of our presidents, leaves his friends and former associates with a distinct sense of loss and of sadness. While few of us had the opportunity of seeing much of him during the last few years many of us came in contact with his vigorous and refreshing personality during the more active period of his life. The writer had the pleasure of a long continued acquaintance with Dr. Hice while he was State Geologist of Pennsylvania and while he was connected with the clay industry of the Beaver Valley.

In the course of many conferences and talks I learned to appreciate his wise counsel and the plain practical sense of our friend who had the ability to clear away all the extraneous parts of a proposition and come down to its essentials. He was a foe of all pretense and was not slow to oppose it. Dr. Hice was loyal to his friends who could always count upon his help and assistance. He was above all meanness and smallness.

The great interest of his life was the economic geology of his beloved Pennsylvania, a state which he served faithfully, often under very discouraging circumstances. At the same time he was much concerned with the work of the AMERICAN CERAMIC SOCIETY and was a constant supporter of its work.

The departure of Richard R. Hice is mourned sincerely by his old associates and his loss leaves a gap in a group which exemplified the spirit of service in no mean degree.

A. V. BLEININGER

The SOCIETY and his many friends suffer a great loss in the death of Mr. Hice. Always anxious to help others from his great store of knowledge, always so friendly and cheerful, his presence at our meetings was an assurance that we would be well paid for any effort spent in attending them. He has gone to his reward but still he will always be with us as his old friends will never forget him. STANLEY G. BURT

I cherish many memories of association with him in the olden days, memories that are now sacred. He was so unassuming, so well posted, so loyal and helpful, that, although I had not seen him for a long time, the memories of the old times were always with me. He did good service and at the time it was needed and counted big.

WM. D. GATES

I was shocked to hear of Mr. Hice's untimely death and with his passing I have lost a friend, an associate, and a genial and lovable companion.

I saw him for the first time on the deck of an excursion boat during the meeting of the N. B. M. A. in Pittsburgh in 1898 when the AMERICAN CERAMIC SOCIETY was born and the thought came to me that there was a man worth while and one whom I wished to know. I came to know him, met him year after year, and my admiration of him, regard for him and appreciation of his fine character, ability, and conscientiousness grew each year.

His was a nature that thought deeply, not given to idle chatter, and when he talked it was direct to the point, without hesitation, and well worth listening to.

When he took you by the hand, looked you in the face, there was no doubt he meant it, and in all the years since I first met him in personal contact with him, in an occasional

letter seeking information from him, there is not a single instance to change in the slightest degree the high esteem in which I held him.

It is not the many words, lightly spoken, making no impression and soon forgotten, that count, but instead the fewer words sincerely meant, and thus I came to know and appreciate Mr. Hice.

I deeply regret that he is gone and I will miss him but I shall ever hold him in cherished remembrance. ELLIS LOVEJOY

With some men, their face is their passport across the frontiers and through the custom houses of acquaintanceship. It leads them on into the sunny parlors of friendship and trust. Such a man was Richard R. Hice. One knew instinctively in his presence that he was confronted by a prince among men. His fine vigorous figure, his large beautifully modeled head, his clear blue eye and his kindly expression, all seemed only a suitable casket for the serene gem of his spirit. So full of candor and honesty, so generous and courtly, so anxious to believe well and so loathe to believe ill or even hear it—and withal, so keen and discriminating in his intellectual powers, so imbued with a passion for the truth.

Hice came into the AMERICAN CERAMIC SOCIETY in its early days, when the circle was small and everyone knew everyone. Primarily a geologist, but with his attention directed toward the study of clays partly by financial interest, and partly by the fascination of the wide unexplored vistas which the least scientific research in that field opened up, he not only at once won his place among us, but broadened the viewpoint and strengthened the grasp of all of us on the fundamentals of our Industry—the Raw Materials.

Although Hice was not a geologist of great prominence or a chemist or ceramist of outstanding productiveness, he was preëminently dependable and sound in his contributions to all three sciences.

While those of the SOCIETY who never knew him, may wonder why we appraise his work so highly, the reason is no secret to the little and fast narrowing circle who knew and loved him. His work seemed to be a part of him—to be imbued with his own genial character. The meetings will never be quite the same to us again. His place cannot be filled. EDWARD ORTON, JR.

So, Hice has been taken from us! Even though we have seen little of him in the past few years, it is a shock to be informed that we will never see him again. The SOCIETY has been fortunate in retaining its charter members. These were men of high character and their usefulness to the industry continues, though the work of the SOCIETY has naturally fallen into the hands of younger men. Hice was not old, and could reasonably be expected to still further add to his accomplishments.

I esteem it a privilege to have known him and to have associated with him during the years of his active interest in the clay industries. I have consulted him on certain clay formations of Pennsylvania and he has been ever ready to give of his knowledge to the individual as well as to the SOCIETY. His genial nature and sympathetic interest in our problems made it a pleasure to meet him.

He had many friends who will miss him. Our SOCIETY has lost a man who did much for it in the years when it needed, and fortunately received, the coöperation of its entire membership. Though many of us still keep in touch with the activities of the younger members and enjoy their companionship, yet we cannot, in the large membership, get as close to each other as we did in the first years of our organization. We love the old members, are always happy to meet them, and are always grieved when any one of them passes away.

Hice, you have done much to help us. We will not forget you. The old guard will close ranks and continue the work. W. D. RICHARDSON

The brief notice of the death of Mr. R. R. Hice came as a great shock to me. I had known Mr. Hice for a number of years both as a friend and a fellow scientist. Throughout all this period I had always felt a warm regard for him, not only because of his interest in scientific and technical subjects, but also because of the good fellowship and sincerity of character which he always exhibited. His loss will be keenly felt by all of us in the AMERICAN CERAMIC SOCIETY who had known him ever since the date of its organization. H. RIES

It was with great regret I learned of the death of another charter member of our AMERICAN CERAMIC SOCIETY. I am sure not only charter members but also our more recent members are made sad. EDWARD C. STOVER

In the recent death of Richard R. Hice, a charter member, we have lost an enthusiastic veteran who was always keenly interested in the advancement of the SOCIETY. For several years he was interested in the manufacture of heavy clay products when the business was largely on a rule-of-thumb basis and he warmly welcomed the formation of an organization that was based on an intelligent, scientific study of its problems. He was a valuable contributor to the discussions at the SOCIETY meetings and was usually present at the summer excursions for visiting the operating plants.

In addition to being a practical ceramist, he was quite active as a geologist and for several years was at the head of the Pennsylvania Geological Survey. In this work he not only pushed the study of the Pennsylvania clays, but also made valuable contributions to the oil and gas industry.

By nature an optimist, he was overflowing with life and energy and was broad enough to change his views in the light of later information. He had a warm, charming personality that endeared him to his associates, who realize that they have lost a loyal, true friend and a valuable contributor to the ceramic industry. H. A. WHEELER

## Resolutions by Board of Trustees

Another charter member and past president of this SOCIETY has passed away. He recorded a wealth of useful ceramic information from which has been developed a great deal of the present ceramic information and manufacturing practices. He gave unselfishly of his time and ability. He loved his fellow men and earned the respect and confidence of all with whom he contacted. He was a scholar respected in the highest science circles. He was an investigator gifted with discernment and vision. He was a worker untiring and generous. He was a man fascinating and forceful. He will be greatly missed. The Board of Trustees of the AMERICAN CERAMIC SOCIETY therefore unanimously resolves,

WHEREAS, in his prime and when he was contributing largely to ceramic science and technology he was stricken and finally taken, and;

WHEREAS, he had for several years devoted a large portion of his time and ability to developing exact ceramic information and was ever anxious to do more, and;

WHEREAS, his generous human qualities brought him into relations which made his vast fund of ceramic information and his keen searching and proof-finding capacity readily available, and;

WHEREAS he served generously from the beginning as member and officer of the AMERICAN CERAMIC SOCIETY;

BE IT RESOLVED that (1) we, the elected members of the Board of Trustees for and in the name of the members of the SOCIETY, here record the appreciation which was broad and without exception of Richard R. Hice for the scholar, the worker, the man, and the fellow he was; and (2) the loss sustained by the many who were known by him and by

the much larger number of his admirers who knew him only by records of his extensive researches.

BE IT ALSO RESOLVED that this record be made in the *Journal of the American Ceramic Society.* E. WARD TILLOTSON, *President*

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## REPORT OF STANDARDS COMMITTEE FOR 1924–25

Since the resignation of W. A. Hull as Chairman of this Committee, in the spring of 1923, three meetings have been held.

### September, 1923 Meeting

The first meeting was called in New York City on September 19, 1923, and was productive of encouraging results. The tentative specifications as published by M. F. Beecher, then Chairman, in the 1921–22 year book were considered and the following business transacted:

(1) Specifications for: (*a*) Sampling Ceramic Materials as Delivered (revised); (*b*) Method for Slaking; (*c*) Scale for Testing Sieves; (*d*) Definitions for Clay Refractories; and (*e*) Method of Test for Refractory Materials under Load were passed and submitted to the General Secretary for vote by the SOCIETY.

(2) Specifications for: (*a*) Sampling of Clay Deposits; (*b*) Chemical Analysis; (*c*) Sag Test; (*d*) Transverse Strength Test; (*d*) Methods for Testing Electrical Porcelain; and (*e*) Methods and Apparatus published in the Appendix (1921–22 Report) were not passed by the Committee but are being continued as tentative.

In addition to the above, the Committee (1) revised, passed and submitted to the General Secretary for vote by the SOCIETY (*a*) Specifications for Whiting, and (*b*) Specifications for Limestone, Quicklime and Hydrated Lime for the Manufacture of Glass. (2) Returned to the General Secretary, for subcommittee to the Divisions in which they originated, Specifications for Flint and Feldspar, together with recommendations and suggestions for their revision.

### February, 1924 Meeting

At the time of this meeting at Atlantic City, on February 5, 1924, the status of Standards, Tentative and Proposed, had remained unchanged.

Mr. Poste reported the work of the Enamel Division on "Acid Tests for Enamels," but stated that the Division did not favor the publication of the results at this time.

A. S. Watts submitted the following definitions, which were developed by Committee C 10 of the American Society for Testing Materials, for consideration:

**Clay** An earthy or stony mineral aggregate, consisting essentially of hydrous silicates of alumina, plastic when sufficiently pulverized and wetted, rigid when dry and vitreous when burned to a sufficient temperature.

**Surface Clay** An unconsolidated, unstratified, sedimentary clay with well-marked cleavage parallel to the bedding.

**Fire Clay** A sedimentary clay of low flux content, usually associated with coal measures.

It was voted that these definitions be printed as tentative.

Prof. Orton addressed the meeting on the importance of research on pyrometric cones to establish the relation between softening point, temperature and time. Prof.

Orton reported on the data which he had obtained in an investigation conducted at his plant on the relative softening points of various makes of pyrometric cones.

E. E. Pressler also addressed the meeting and explained in as much detail as the limited time would permit, a system of clay tests developed by him at the Ohio State University.

It was passed that the Chairman be instructed to appoint a committee to cooperate with the Bureau of Standards on a proposed investigation of pyrometric cones.

From a general discussion of the duties of this Committee it was obvious that the majority of the members favored the policy of having the Chairman assign to the special divisions constituting the committee definite problems for solution. Accordingly the following assignments were made:

**Committee on Definitions** (A. S. Watts, Chairman.) Define the terms: (1) *Porous*, (2) *Semi-vitreous*, (3) *Incipient Vitrification*, (4) *Vitrified*, and (5) *Maturing Temperature.*

**Committee on Raw Materials** (D. W. Ross, Chairman.) Consider: (*a*) Specifications for Quicklime and Hydrated Lime for the Manufacture of Silica Brick (Bureau of Standards Circular No. 153); (*b*) Tentative Specifications for Flint. (NOTE: The Specification for Silica Sand for Glass Making has not as yet been officially presented to the Standards Committee by the Glass Division); (*c*) Tentative Specifications for Feldspar (1921–22 Report).

**Committee on Tests** (G. A. Bole, Chairman.) Consider: (*a*) "Tentative Method for Conducting Draw Trial" (1921–22 Report Appendix); (*b*) Work presented to the Committee by E. E. Pressler.

**Committee on Products** (C. F. Geiger, Chairman.) Consider: "Proposed Federal Specifications Board Specifications for Fire Clay Brick, and for Fire Clay." (NOTE: The Specifications for Fire Clay Brick has since been adopted by the F. S. B. as Specification number 268.)

## February, 1925 Meeting

The meeting was called at 5:20 P.M. on Wednesday, Feb. 18. Due to the unusually large number of interesting papers on the several Divisional programs, and the fact that no time had been set aside for Committee meetings, it was practically impossible to get together a quorum.

The following members were present: M. C. Booze, G. A. Bole, C. F. Geiger, A. S. Watts, R. F. Geller.

Mr. Geiger, as Chairman of the Committee on Products, had no formal report to make. After a limited discussion it was decided to submit the specifications for Fire Clay Brick as adopted by the Federal Specifications Board, but omitting the Simulated Service Test, to the Committee as a whole for approval, by ballot, as tentative.

The Committee on Tests, through Mr. Bole as Chairman, submitted a voluminous report indicative of a careful consideration of the revised methods for clay testing presented to the committee by Mr. Pressler. The following summary of conclusions was presented by Mr. Bole: "(1) That the material be worked up into a system of tests with full instructions as to method of carrying them out. (2) A justification for each test. Where possible the justification should take the form of comparative data to show that these tests are superior to methods now in use. (3) That the several tests be checked in several laboratories. I will be willing to endeavor to make arrangements for the various laboratory tests through our committee after Mr. Pressler has completed the first two phases of the work."

D. W. Ross, as Chairman of the Committee on Raw Materials, had formally submitted the following recommendations prior to the meeting:

(A) That the "Specifications for Quicklime and Hydrated Lime for use in the Manufacture of Silica Brick" as given in Bureau of Standards Circular Number 153 be submitted to the AMERICAN CERAMIC SOCIETY for confirmation or rejection as a tentative specification, if, and as soon as the A. S. T. M. confirms it as a standard specification for that society.

(B) That the development of specifications on flint and feldspar be left entirely to Frank Riddle's Committee of the White Ware Division until said Committee shall have made their final report on the subject.

The Committee on Definitions, with A. S. Watts as Chairman, was also very active during the past year. While progress is being made, no definite conclusions have been reached, and it is hoped that the interest of this Committee in developing definitions for certain ceramic terms will not lag during the coming year. Chairman Watts also wishes the attention of the Committee called to the following definitions which had been revised and adopted as standard by the A. S. T. M.:

**Clay** — An earthy or stony aggregate consisting essentially of hydrous silicates of alumina, plastic when sufficiently pulverized and wetted, rigid when dry and vitreous when burned to a sufficiently high temperature.

**Surface Clay** — An unconsolidated, unstratified clay, occurring on the surface.

**Fire Clay** — A sedimentary clay of low flux content. (NOTE: It is usually associated with coal measures.)

**Shale** — A thinly stratified, consolidated sedimentary clay with well-marked cleavage parallel to the bedding.

The Chairman was requested to submit the recommendations of Messrs. Ross and Watts to the Committee as a whole.

It has long been felt by various members of this Committee, and was again expressed at this meeting, that the Standards Committee and other Committees general to the SOCIETY be required to report to the SOCIETY at the annual meetings. It has been noted with considerable satisfaction that the tentative schedule for the meeting in Atlanta provides a time for such reports.

There was placed before the Committee for consideration the proposition of discontinuing the Standards Committee as an organization for the aggressive promotion of standards and tests for ceramic material, and to reorganize simply as a passive committee whose functions would be to supply the necessary contact with other associations and societies in their work on standards and tests. It was the opinion of the committee that it is not possible, with the present organization, to progress as rapidly as might be desired or to obtain the necessary personnel and finances to insure such progress; however, it was not felt that the committee should at this time approve steps as drastic as outlined in the original proposition.

The Chairman, in accordance with the instructions of the committee, had appointed P. H. Bates as representative of the Standards Committee in the special Commission to promote, and coöperate with the Bureau of Standards, in the investigation of pyrometric cones. This Special Commission consisted of Ed. Orton, Jr. and W. E. Mayer (producers); and M. C. Booze, James Turner, P. H. Bates (Chairmen), and W. H. Fulweiler (non-producers). Following a conference[1] with the members of the Bureau staff, and aided by direct financial aid from Prof. Orton, active work was started on two distinct lines of work: (1) the accurate determination of the relation between cone composition, temperature of softening, and heat applied (under C. O. Fairchild); (2) the de-

[1] The Bureau had considered the problem and constructed one furnace prior to the meeting.

termination of the relative softening points of typical American, English, German and French Cones (under R. F. Geller).

Due to exacting nature of Mr. Fairchild's work it was not possible in the first phase of the work, to advance much beyond the establishment of test methods and apparatus. In the second phase it was possible to complete the work for cones ranging from 010 to 20 and it is believed that the relative softening points of the four makes of cones tested had been fairly well established in the range given. A report of this work was made to the SOCIETY in General Session on Wednesday, February 18.

The Committee adjourned at 6.05 P.M. with the time of the next meeting left to the call of the Chairman.

While this Committee, as stated by some members, may be "making satisfactory progress" the actual work accomplished is so lamentably small as to seem hopelessly insignificant when compared with that which remains to be done.

At the present time the SOCIETY has: (1) Six accepted standards; (2) Seven methods and specifications recommended for acceptance as standard; (3) Eight (including silica sand) tentative methods and specifications.

The six standards were adopted in 1920 and should be carefully reconsidered to ascertain whether or not they still represent the best available data on the subject.

The seven recommended for acceptance could probably bear reconsideration by this time, for, here again, the progress of the industry in two years may have made certain details obsolete.

The eight tentative methods and specifications should either be recalled or revised, if necessary, and passed. It has been said that in this age one must "run to stand still," from which we are left to infer that "to stand still is to deteriorate." A specification is seldom a fundamental truth, but rather the nearest to the truth that can be determined with available data and must accordingly be changed as the data changes.

In addition to the above the committee should at least formally consider the following results of Federal Activities:

B. of S. Cir. 119. Spec. for Lime Flint Glass Tumblers.
164. U. S. Govt. Master Spec. for Flat Glass for Glazing Purposes.
118. Limestone, Quicklime and Hydrated Lime for Use in the Manufacture of Glass.
121. Glass Tableware.
243. Vitrified Chinaware.
122. Glass Lantern Globes and Lamp Chimneys.

DIV. OF SIMPLIFIED PRACTICE

B. of S. Cir. 7. Face Brick and Common Brick.
5. Hotel Chinaware.
?. (Cafeteria and Restaurant.)
1. Paving Brick, Vitrified.
10. Milk Bottles and Milk Bottle Caps.
12. Hollow Building Tile.

The work of this Committee peculiarly demands the active coöperation of technical organizations either through representatives on the Committee itself, or in their respective Divisions. Therein lies, no doubt, one of the principal reasons for the slowness of progress. It is customarily accepted that one man, on any Committee, does practically all the work; "one man definitions," however, are rarely practicable.

In this connection it is a noticeable fact that such progress as has been made is directly traceable to a few men (past and present) on the Committee itself and to Federal and University Laboratories. Active interest is not characteristic of the industry, and specifications will inevitably pine away and die without that interest.

It is also believed that the work of the Committee could be greatly assisted if it were possible to finance the expense incident to at least three meetings a year. This would help in two ways: (1) The SOCIETY would take an active interest in the work of the Committee if it had money invested in it; (2) The Committee itself would feel a moral obligation to make some return for the money expended by the SOCIETY.

Due to the summer meeting being scheduled for Toronto it will probably be impossible to hold a meeting prior to the next annual Convention. Little progress can be expected but if the Standards Committee wishes to maintain its identity among the living, those of its members who represent divisions will have to preach the gospel in those divisions to the end that at least a few of the assignments indicated in this report may be brought nearer to completion.

Respectfully submitted,

R. F. GELLER, *Chairman*, Standards Committee.

Bureau of Standards, April 11, 1925.

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## CZECHOSLOVAKIAN CERAMISTS TO BE HOSTS

Rudolph Barta, General Secretary of the Czechoslovakian Ceramic Society has issued an invitation to the members of the AMERICAN CERAMIC SOCIETY to join in a meeting of the three Ceramic Societies, in Prague, Czechoslovakia, in March, 1926. The English Ceramic Society will be there and it is supposed that the German Ceramic Society will also join the meeting.

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# NOTES AND NEWS

## NOTES FROM BUREAU OF MINES

**Domestic vs. Foreign Clays**

The Bureau is receiving samples of English china clays from commercial shipments, sampled as delivered. These clays are to be tested as to their chemical, physical, and microscopic properties in the laboratory, concurrently with their commercial utilization. In this way it is hoped that information will be obtained that will throw light upon the quality of clays now received into this country, against which considerable complaint has been raised among users. The investigation is being undertaken at the request of the Research Committee of the U. S. Potters Association, A. V. Bleininger, Chairman.

**Mr. Helser to Lisbon**

Mr. P. D. Helser who has been with the Bureau for the past two years in the capacity of ceramic engineer and assistant superintendent of the Columbus Station has severed his connections with the Bureau of Mines to take a position at the Lisbon plant of the R. Thomas and Sons Company. It is with regret that the Bureau loses Mr. Helser. It is just another example of the oft repeated performance of a good man becoming better equipped and better known through Bureau service and being taken into the industry to become a valuable unit in our industrial development. Well trained men are the most valuable product the Government Bureaus can offer industry.

**Dolomite Clinker**

Dolomite clinker resulting from the experiments which the Bureau has been carrying on during the past five years is being produced at the rate of 100 tons daily at a commercial plant and is being tested

on a large scale at several open hearth plants throughout the country. The tests so far indicate that it is giving superior service to any commercial clinker.

**Pullman Laboratory** The laboratory car Metchnikoff has been transferred from the Medical Department of the U. S. Army to the Department of the Interior, Bureau of Mines, and has been made available to the Ceramic Experiment Station at Columbus. It is now parked on the campus of Ohio State University and has been renamed the Keramos.

Laboratory equipment is to be installed after which it is likely that the car will be used in connection with certain coöperations that are now underway but which have been somewhat handicapped due to inadequate laboratory facilities in the field and living quarters for the investigators.

**Fellowship Men** The following men are candidates for degrees at Ohio State University after having finished their thesis investigation in the Bureau: Mr. Leonard F. Sheerar, M.A., and Mr. A. Ernest MacGee, Ph.D.

These fellowship investigations are published each year as bulletins by the Ohio State Engineering Experiment Station in coöperation with the Bureau of Mines.

Mr. MacGee will remain with the Bureau to take up work as a coöperative research fellow employed by the Ceramic Research Association. Mr. Sheerar will go with the Robinson Clay Products Company at Dover, Ohio.

Mr. MacGee, using a new method, has determined the heat necessary to fire various clays and ceramic bodies up to 1050°C. Mr. Sheerar has determined (quantitatively) the effect of oxidizing, neutral, and reducing atmospheres upon the deformation under load of refractories containing varying percentages of iron. The effect of the method of manufacture was also included in the tests.

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## SOCIETY OF GLASS TECHNOLOGY MEETING

At the Annual General Meeting of this Society held in Sheffield on April 22, S. C. Halse was succeeded as President by T. C. Moorshead. To fill vacancies in the Council the following were elected: As Vice-Presidents, W. Butterworth and J. H. Davidson; as ordinary members of Council, Messrs. B. P. Dudding, E. A. Hailwood, H. J. C. Johnston, E. Meigh and G. Simpson. Councillor J. Connolly was reëlected General Treasurer, and W. M. Clark, American Treasurer. W. E. S. Turner was appointed Honorary Secretary and C. S. Davey and Dennis Wood were elected Auditors. The retiring President, S. C. Halse, took as the subject of his Presidential address "The Present State of the British Glass Industry." He pointed out that in certain important branches of the industry the unemployment returns provided no index to the relative state of the industry now and prior to the War. The wholesale introduction of automatic machinery had considerably reduced the number of men employed while the production was simultaneously greatly increased.

At the Ordinary General Meeting which followed the Annual General Meeting, the Society departed from its usual practice of having a series of technical papers. Instead, W. E. S. Turner, at the invitation of the Council, delivered a popular illustrated lecture on "Glass as an Instrument of Human Progress." Prof. Turner dealt with his subject in two main sections, namely, the place of glass in extending man's mental horizon and the use of glass in providing protection, comforts and luxury. In the first section he dealt with the vast extent of knowledge gained through the application of the microscope, telescope, spectroscope, ultramicroscope, camera and chemical apparatus. The second part dealt with the use of heating and illuminating glass and sheet glass for

many purposes and included reference to special spectacle glasses and F. E. Lamplough's new "Vita Glass" for transmitting ultra-violet light and to its use in hospitals, etc. Reference was also made to the preëminent position occupied at present by British-made optical glass.

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## A RESOLUTION PASSED AT AMERICAN CONSTRUCTION COUNCIL'S CONFERENCE ON THE ELIMINATION OF CONSTRUCTION PEAKS AND DEPRESSIONS, NEW YORK, MAY 9th, 1925

RESOLVED: It is the sense of this conference that the elimination of construction peaks and depressions can be accomplished only by the education of the public and this education can be brought about only by the united effort of all those interested in and affected by greater stability of the construction industry—owners, manufacturers and distributors of materials, transportation agencies and public officials as well as those who have to do with the initiation and prosecution of construction operations.

Therefore be it further resolved that it is the sense of this conference that a general coördinating committee, to be appointed jointly by the American Construction Council and the railways of the country and to include representatives of appropriate bodies within the industry, be organized in order that the publicity of these associations and agencies can be coördinated and unified in a general campaign of publicity for the country as a whole.

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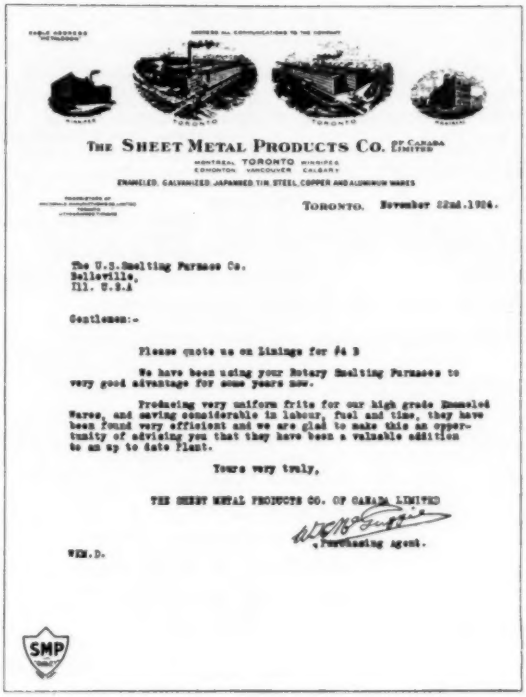
## CALENDAR OF CONVENTIONS

| Organization | Date | Place |
|---|---|---|
| **Am. Assn. Advancement of Science** | Dec. 28–Jan. 2 | Kansas City, Mo. |
| **Am. Assn. of Flint and Lime Glass Mfrs.** | July, 1925 | Atlantic City, N. J. |
| **AMERICAN CERAMIC SOCIETY** | | |
| (**Annual Meeting**) | Feb. 8–13, 1926 | Atlanta, Ga. |
| (**Summer Meeting**) | July 4–11, 1925 | Toronto, Canada |
| (**Fall Meeting**) | Oct. 1, 1925 | New York City |
| **Am. Electrochemical Society** | Sept. 24–26, 1925 | Chattanooga, Tenn. |
| **Am. Engineering Council** | Jan., 1926 | |
| **Am. Foundrymen's Association** | Oct. 5–9, 1925 | Syracuse, N. Y. |
| **Am. Gas Association** | Oct. 12–16, 1925 | Atlantic City, N. J. |
| **Am. Inst. of Chemical Engineers** | June 22–25, 1925 | Providence, R. I. |
| | July 13–16, 1925 | Leeds, England |
| **Am. Inst. of Min. and Met. Engineers** | Aug. 31–Sept. 5, 1925 | Salt Lake City, Utah |
| **Coal Mining Institute of America** | Dec. 9–11, 1925 | Pittsburgh, Pa. |
| **Am. Soc. of Mechanical Engineers** | | |
| (**Annual Meeting**) | Nov. 30–Dec. 3 | New York City |
| (**Pacific Coast Regional Meeting**) | June 22–25, 1925 | Portland, Ore. |
| **Am. Soc. for Testing Materials** | June 22–26, 1925 | Atlantic City, N. J. |
| **Am. Zinc Institute** | April 27–28, 1925 | St. Louis, Mo. |
| **Assn. Iron and Steel Elec. Engineers** | Sept., 1925 | Philadelphia, Pa. |
| **Chemical Equipment Exposition** | June 22–27, 1925 | Providence, R. I. |
| **Common Brick Manufacturers Assn.** | Feb., 1925 | |

| Organization | Date | Place |
|---|---|---|
| **Institution of Chemical Engineers** | July 13–16, 1925 | Leeds, England |
| **Manufacturing Chemists' Association** | June, 1925 | New York City |
| **Mining and Met. Society of America** | Jan. 12, 1925 | New York City |
| **Natl. Association of Manufacturers** | Oct. 26–28, 1925 | St. Louis, Mo. |
| **Natl. Chemical Equipment Assn.** | June 22–27, 1925 | Providence, R. I. |
| **Natl. Exposition of Power and Mechanical Engineers** | Nov. 30–Dec. 5 | New York City |
| **Natl. Exposition of Chem. Industries** | Sept. 28–Oct. 3 | New York City |
| **Natl. Ornamental Glass Mfrs. Assn.** | June 4, 1925 | Pittsburgh, Pa. |
| **Natl. Paving Brick Mfrs. Assn.** | Jan., 1926 | |
| **Natl. Safety Council** | Sept. 28–Oct. 2 | Cleveland, O. |
| **New Jersey Clay Workers Assn.** | June, 1925 | Trenton, N. J. |
| **Sand-Lime Brick Assn.** | Feb. 9–15, 1926 | New Orleans, La. |
| **Sheet Metal Ware Assn.** | June, 1925 | Cincinnati, O. |
| **Soc. of Chem. Industry** | July 13–16, 1925 | Leeds, England |
| **Natl. Society for Vocational Education** | Dec. 3–5, 1925 | Cleveland, Ohio |
| **Natl. Exposition of Coal Mining Machinery** | Dec. 2–5, 1925 | Cincinnati, O. |

# LARGE CANADIAN ENAMELING PLANT USING BATTERY OF U. S. ROTARY ENAMEL SMELTING FURNACES



THE SHEET METAL PRODUCTS CO. OF CANADA LIMITED

MONTREAL TORONTO WINNIPEG
EDMONTON VANCOUVER CALGARY

ENAMELLED, GALVANIZED, JAPANNED TIN, STEEL, COPPER AND ALUMINUM WARES

TORONTO, November 22nd.1924.

The U.S.Smelting Furnace Co.
Belleville,
Ill. U.S.A

Gentlemen:-

Please quote us on Linings for #4 B

We have been using your Rotary Smelting Furnaces to very good advantage for some years now.

Producing very uniform frits for our high grade Enameled Wares, and saving considerable in labour, fuel and time, they have been found very efficient and we are glad to make this an opportunity of advising you that they have been a valuable addition to an up to date Plant.

Yours very truly,

THE SHEET METAL PRODUCTS CO. OF CANADA LIMITED

Purchasing agent.

WEM.D.

SMP

*Years of Efficient Service*

*Very Uniform Frits at a Saving in Fuel, Labor and Time*

*A Valuable Addition*

**SIZES AND CAPACITIES**

| No. 1 | No. 2 | No. 3 | No. 4 | No. 4-B |
|---|---|---|---|---|
| 60 lb. | 150 lb. | 350 lb. | 750 lb. | 1200 lb. |

***Description, Photographs, Specifications and Prices Mailed Promptly.***

## THE U. S. SMELTING FURNACE CO.

**BELLEVILLE, ILLINOIS, U. S. A.**

## BUYERS' GUIDE

### A

**Air Compressors**
General Electric Co.

**Alumina (Hydrate and Calcined)**
Pennsylvania Salt Mfg. Co.

**Alundum (Refractory Products)**
Norton Co.

**Auger Machines**
Chambers Brothers Co.

**Automatic Brick Machinery**
Lancaster Iron Works, Inc.

**Automatic Cutters**
Chambers Brothers Co.

**Automatic Stove Rooms**
Philadelphia Drying Machinery Co.

**Automatic Temperature Control**
Brown Instrument Co.
Engelhard, Chas., Inc.
Leeds & Northrup Co.

### B

**Ball Mills**
Hardinge Co.
McDanel Refrac. Porcelain Co.
Mueller Machine Co., Inc.

**Batts (Alundum-Crystolon)**
Norton Co.

**Bitstone**
Potters Supply Co.

**Bituminous Coal**
Seaboard Fuel Corp.

**Blocks (Refractory)**
Norton Co.

**Boats, Combustion**
Norton Co.

**Borax**
American Trona Corp.
Innis, Speiden & Co.

**Boric Acid (Crystal, Granular or Powder)**
American Trona Corp.
Innis, Speiden & Co.

**Brick Making Machinery**
Chambers Brothers Co.

**Bricks (Refractory-Alundum-Crystolon)**
Norton Co.

**Burners (Oil)**
Best, W. N. Corp.

### C

**Cars (Clay)**
Lancaster Iron Works, Inc.

**Carbonates (Barium-Lead)**
Innis, Speiden & Co.

**Caustic Soda**
Pennsylvania Salt Mfg. Co.

**Cements**
Norton Co.

**Ceramic Chemicals**
Drakenfeld and Co., B. F.
Harshaw, Fuller and Goodwin Co.
Metal & Thermit Corp.
Paper Makers Importing Co., (Inc.)
Roessler and Hasslacher Chemical Co.
Titanium Alloy Mfg. Co.
Vitro Mfg. Co.

**Ceramic Plant Equipment**
Ceramic Engineering Co.
Chambers Brothers Co.
Mueller Machine Co., Inc.
Philadelphia Drying Machinery Co.
Proctor and Schwartz, Inc.

**Clay (Ball)**
Paper Makers Importing Co.
Potters Supply Co.
United Clay Mines Corp.

**Clay (China)**
Drakenfeld and Co., B. F.
Edgar Brothers Co.
Paper Makers Importing Co., (Inc.)
Roessler & Hasslacher Chemical Co
United Clay Mines Corp.

**Clay (Electrical—Porcelain)**
Edgar Brothers Co.
Paper Makers Importing Co., (Inc )
United Clay Mines Corp.

**Clay (Enamel)**
Edgar Brothers Co.
Paper Makers Importing Co.
Metal & Thermit Corp.
United Clay Mines Corp.
Vitro Mfg. Co.

**Clay (Fire)**
Edgar Brothers Co
Paper Makers Importing Co., (Inc.)
Potters Supply Co.
United Clay Mines Corp.

**Clay (Potters)**
Paper Makers Importing Co.
United Clay Mines Corp.

**Clay (Sagger)**
Edgar Brothers Co.
Paper Makers Importing Co., (Inc.)
Potters Supply Co.
United Clay Mines Corp.

**Clay Cleaning Machinery**
Lancaster Iron Works, Inc.

*Mark the item ☐ that interests you*

☐ Coal or Sand Screens—double crimped
☐ Bran Duster grade wire cloth
☐ Tinned mill screen cloth
☐ Brass, copper, bronze, steel wire cloth
☐ Market grade wire cloth: brass, copper
☐ Extra fine phosphor bronze wire cloth
☐ Monel Metal wire cloth
☐ Standard Testing Sieves
☐ Dipping Baskets
☐ Please send Catalog

If any other metal is desired, please specify it as we make wire cloth out of all metals: Aluminum, copper, brass, bronze, phosphor bronze, nickel, steel, gold, silver, monel metal, platinum, nichrome, and special alloys.

Specify the length, width, size of wire, space, etc. Or, send us a sample of the wire cloth you want duplicated. Probably we have it in stock.

**Newark Wire Cloth Company**
**355-369 Verona Avenue** **Newark, New Jersey**
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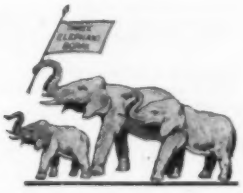
**99.5% PURE**
Its uniform high quality guarantees the excellence of your product.
We also make Boric Acid guaranteed 99.5% Pure
Write for our price and samples today.



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***Quality*** ***Uniformity*** ***Service***
**LUSTERLITE ENAMELS**
**Manufacturers**
**FURNACES - - SPEED FORKS - - ENAMELS**
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**Supplies & Equipment**
***STOCK CARRIED***
**Chicago Vitreous Enamel Product Company**
**1407-47 S. 55th Court, Cicero, Ill., U. S. A.**

## BUYERS' GUIDE

### A

**Air Compressors**
General Electric Co.

**Alumina (Hydrate and Calcined)**
Pennsylvania Salt Mfg. Co.

**Alundum (Refractory Products)**
Norton Co.

**Auger Machines**
Chambers Brothers Co.

**Automatic Brick Machinery**
Lancaster Iron Works, Inc.

**Automatic Cutters**
Chambers Brothers Co.

**Automatic Stove Rooms**
Philadelphia Drying Machinery Co.

**Automatic Temperature Control**
Brown Instrument Co.
Engelhard, Chas., Inc.
Leeds & Northrup Co.

### B

**Ball Mills**
Hardinge Co.
McDanel Refrac. Porcelain Co.
Mueller Machine Co., Inc.

**Batts (Alundum-Crystolon)**
Norton Co.

**Bitstone**
Potters Supply Co.

**Bituminous Coal**
Seaboard Fuel Corp.

**Blocks (Refractory)**
Norton Co.

**Boats, Combustion**
Norton Co.

**Borax**
American Trona Corp.
Innis, Speiden & Co.

**Boric Acid (Crystal, Granular or Powder)**
American Trona Corp.
Innis, Speiden & Co.

**Brick Making Machinery**
Chambers Brothers Co.

**Bricks (Refractory-Alundum-Crystolon)**
Norton Co.

**Burners (Oil)**
Best, W. N. Corp.

### C

**Cars (Clay)**
Lancaster Iron Works, Inc.

**Carbonates (Barium-Lead)**
Innis, Speiden & Co.

**Caustic Soda**
Pennsylvania Salt Mfg. Co.

**Cements**
Norton Co.

**Ceramic Chemicals**
Drakenfeld and Co., B. F.
Harshaw, Fuller and Goodwin Co.
Metal & Thermit Corp.
Paper Makers Importing Co., (Inc.)
Roessler and Hasslacher Chemical Co.
Titanium Alloy Mfg. Co.
Vitro Mfg. Co.

**Ceramic Plant Equipment**
Ceramic Engineering Co.
Chambers Brothers Co.
Mueller Machine Co., Inc.
Philadelphia Drying Machinery Co.
Proctor and Schwartz, Inc.

**Clay (Ball)**
Paper Makers Importing Co.
Potters Supply Co.
United Clay Mines Corp.

**Clay (China)**
Drakenfeld and Co., B. F.
Edgar Brothers Co.
Paper Makers Importing Co., (Inc.)
Roessler & Hasslacher Chemical Co
United Clay Mines Corp.

**Clay (Electrical—Porcelain)**
Edgar Brothers Co.
Paper Makers Importing Co., (Inc.)
United Clay Mines Corp.

**Clay (Enamel)**
Edgar Brothers Co.
Paper Makers Importing Co.
Metal & Thermit Corp.
United Clay Mines Corp.
Vitro Mfg. Co.

**Clay (Fire)**
Edgar Brothers Co
Paper Makers Importing Co., (Inc.)
Potters Supply Co.
United Clay Mines Corp.

**Clay (Potters)**
Paper Makers Importing Co.
United Clay Mines Corp.

**Clay (Sagger)**
Edgar Brothers Co.
Paper Makers Importing Co., (Inc.)
Potters Supply Co.
United Clay Mines Corp.

**Clay Cleaning Machinery**
Lancaster Iron Works, Inc.

*Mark the item ☐ that interests you*

☐ Coal or Sand Screens—double crimped
☐ Bran Duster grade wire cloth
☐ Tinned mill screen cloth
☐ Brass, copper, bronze, steel wire cloth
☐ Market grade wire cloth: brass, copper
☐ Extra fine phosphor bronze wire cloth
☐ Monel Metal wire cloth
☐ Standard Testing Sieves
☐ Dipping Baskets
☐ Please send Catalog

If any other metal is desired, please specify it as we make wire cloth out of all metals: Aluminum, copper, brass, bronze, phosphor bronze, nickel, steel, gold, silver, monel metal, platinum, nichrome, and special alloys.

Specify the length, width, size of wire, space, etc. Or, send us a sample of the wire cloth you want duplicated. Probably we have it in stock.

**Newark Wire Cloth Company**
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**THREE ELEPHANT BORAX**
**99.5% PURE**
Its uniform high quality guarantees the excellence of your product.
We also make Boric Acid guaranteed 99.5% Pure
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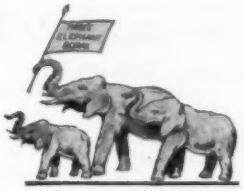

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**1407-47 S. 55th Court, Cicero, Ill., U. S. A.**

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**Clay Handling Machinery**
Hadfield-Penfield Steel Co.
Mueller Machine Co., Inc.

**Clay Miners**
Edgar Brothers Co.
Paper Makers Importing Co., (Inc.)
United Clay Mines Corp.

**Clay Storage Systems**
Lancaster Iron Works, Inc.

**Clay (Wad)**
Paper Makers Importing Co., (Inc).
Potters Supply Co.
United Clay Mines Corp.

**Clay (Wall Tile)**
Paper Makers Importing Co., (Inc).
United Clay Mines Corp.

**Clay Washing Machinery**
Mueller Machine Co., Inc.

**Clay Working Machinery**
Hadfield-Penfield Steel Co.
Mueller Machine Co., Inc.

**Cloth (wire)**
Newark Wire Cloth Co.

**Coal-(Bituminous)—**
Seaboard Fuel Corp.

**Colors**
Drakenfeld and Co., B. F.
Harshaw, Fuller and Goodwin Co.
Innis, Speiden & Co.
Roessler and Hasslacher Chemical Co.
Vitro Mfg. Co.

**Conditioning Machinery**
Philadelphia Drying Machinery Co.
Proctor & Schwartz, Inc.

**Cones (Filter)**
Norton Co.

**Conical Mills**
Hardinge Co.

**Controllers**
General Electric Co.

**Conveyors (Belt) (Cable)**
Lancaster Iron Works, Inc.

**Conveyors (Clay, Sand, Brick, etc.)**
Hadfield-Penfield Steel Co.
Philadelphia Drying Machinery Co.
Mueller Machine Co., Inc.

**Controllers, (Automatic Temperatures)**
Brown Instrument Co.
Engelhard, Charles, Inc.
Leeds & Northrup Co.

**Cores (Alundum Furnace)**
Norton Co.

**Cornwall Stone**
Pennsylvania Pulverizing Co.

**Crucibles (Filter-Melting-Ignition)**
Norton Co.
Potters Supply Co.

**Crushers**
Chambers Brothers Co.
Hadfield-Penfield Steel Co.
Hardinge Co.
Lancaster Iron Works, Inc.
Mueller Machine Co., Inc.

## D

**Decorating Supplies**
Drakenfeld and Co., B. F.
Harshaw, Fuller and Goodwin Co.
Roessler and Hasslacher Chemical Co.
Vitro Mfg. Co.

**Discs (Alundum-Porous-Filter)**
Norton Co.

**Dishes (Alundum-Filtering-Ignition)**
Norton Co.

**Disintegrators**
Chambers Brothers Co.
Hadfield-Penfield Steel Co.
Lancaster Iron Works, Inc.
Mueller Machine Co., Inc.

**Dolomite**
Innis, Speiden & Co.

**Dryers (China Ware—Porcelain)**
Philadelphia Drying Machinery Co.
Proctor and Schwartz, Inc.

**Dryers (Steam Pipe Rack)**
Lancaster Iron Works, Inc.

**Drying Machinery**
Philadelphia Drying Machinery Co.
Proctor and Schwartz, Inc.

## E

**Electrical Instruments**
Brown Instrument Co.
Engelhard, Charles, Inc.
Leeds & Northrup Co.

**Electric Co. Meters (Recorders)**
Brown Instrument Co.
Engelhard, Chas., Inc.

**Electrical Porcelain Machinery**
Mueller Machine Co., Inc.

**Enameling Equipment, Complete**
Chicago Vitreous Enamel Product Co.
Ferro Enamel Supply Co.
The Porcelain Enamel & Mfg. Co.

# "HURRICANE"

## *CERAMIC DRYERS*

For rapid, thorough drying

Pay for themselves quickly and repeatedly.

*Automatic and Truck Systems*

Uniform Quality of Output

*Stove Rooms and Mangles*

**THE PHILADELPHIA DRYING MACHINERY COMPANY**

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**Philadelphia, Pa.**

HURRICANE
*Ideal Drying Every Day*

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**New England Agency:**
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*53 State St., Boston, Mass.*

WABIK
QUALITY M PRODUCTS
METAL

After an exhaustive study of the requirements of the Enameling Industry we are producing:

## WABIK METAL SPECIAL VITREOUS ENAMELING SHEETS

Unlike ordinary steel sheets, warping and blistering is reduced to a minimum, thus increasing the Enameler's output and profit.

Many of the leading plants now recognize "WABIK METAL" as the supreme stock for that beautiful permanent lustre which is so essential in Table Tops, Stove Parts, Refrigerator Parts, Signs, etc.

## THE MANSFIELD SHEET & TIN PLATE CO.

**MANSFIELD, OHIO**

## BUYERS' GUIDE (continued)

**Enameling Furnaces**
Chicago Vitreous Enamel Product Co.
Combustion Utilities Corp.
Ferro Enamel Supply Co.
General Electric Co.
Holcroft & Co.
Surface Combustion Co.
The Carborundum Co.
(*Carboradiant*)
The Porcelain Enamel & Mfg. Co.
U. S. Smelting Furnace Co.
Vitro Mfg. Co.

**Enameling Furnaces** (Electric)
General Electric Co.

**Enameling Muffles**
Parker-Russell Mining & Mfg. Co.
The Carborundum Co.
(*Carbofrax*)

**Enameling, Practical Service**
Chicago Vitreous Enamel Product Co.
Ferro Enamel Supply Co.
The Porcelain Enamel & Mfg. Co.
Vitro Mfg. Co.

**Enamels, Porcelain**
Chicago Vitreous Enamel Product Co.
Ferro Enamel Supply Co.
The Porcelain Enamel & Mfg. Co.
Vitro Mfg. Co.

**Engineering Service**
Chambers Brothers Co.
Hadfield-Penfield Steel Co.
Tefft, C. Forrest

**Equipment** (Porcelain Enameling)
Chicago Vitreous Enamel Product Co.
The Porcelain Enamel & Mfg. Co.

**Extruding Machines** (Lab. Use)
Chambers Brothers Co.

## F

**Feldspar**
Drakenfeld and Co., B. F.
Eureka Flint & Spar Co.
Harshaw, Fuller and Goodwin Co.
Innis, Speiden & Co. (*Isco*)
Maine Feldspar Co.
Pennsylvania Pulverizing Co.
Roessler & Hasslacher Chemical Co.

**Filtering Machinery**
Mueller Machine Co., Inc.

**Fire Brick**
Parker-Russell Mining & Mfg. Co.
The Carborundum Co.

**Flint**
Eureka Flint & Spar Co.
Innis, Speiden & Co. (*Carrara*)
National Silica Co.
Pennsylvania Pulverizing Co.

**Frit**
Ferro Enamel Supply Co
Porcelain Enamel & Supply Co.
Vitro Mfg. Co.

**Fuel**
Seaboard Fuel Corp.

**Furnaces**
Chicago Vitreous Enamel Product Co.
Ferro Enamel Supply Co.
Holcroft & Co.
Parker-Russell Mining & Mfg. Co.
The Carborundum Co. (*Carboradiant*)
The Porcelain Enamel & Mfg. Co.
The Surface Combustion Co.
U. S. Smelting Furnace Co.

**Furnaces** (Electrical)
Engelhard, Chas., Inc.
General Electric Co.
Holcroft & Co.

## G

**Glazes and Enamels**
Chicago Vitreous Enamel Product Co.
Ferro Enamel Supply Co.
Harshaw, Fuller and Goodwin Co.
Roessler and Hasslacher Chemical Co.
The Porcelain Enamel & Mfg. Co.
Vitro Mfg. Co.

**Granulators**
Lancaster Iron Works, Inc.

**Gold**
Drakenfeld, and Co., B. F.
Harshaw, Fuller and Goodwin Co.
Roessler and Hasslacher Chemical Co.
Vitro Mfg. Co.

## H

**Hearths**
The Carborundum Co.
(Carbofrax heat treating)

**Hygrometers** (Electric)
Engelhard, Chas., Inc.

## I

**Impervite** (Refractory and Hard Porcelain)
Engelhard, Charles, Inc.

**Infusorial Earth**
Innis, Speiden & Co.

**Iron** (Enameling)
American Rolling Mill Co.
The Mansfield Sheet & Tin Plate Co.
United Alloy Steel Corp.

# ARMCO LABEL

## Increase your sales with this label

THIS label has a cash value. It will work for you—help sell your products—and never ask for pay. Hundreds of thousands of buyers have learned through our National advertising, that the ARMCO label is a mark of quality. Whenever they buy enameled products they look for the blue and gold label.

If you are not already putting the ARMCO identification label on the products you make entirely or in part of ARMCO Ingot Iron, begin doing it now. It is one of the most effective methods of increasing your volume of sales.

**THE AMERICAN ROLLING MILL CO.**
**MIDDLETOWN, OHIO**
The ARMCO International Corporation
Cable Address—ARMCO, Middletown

Fill out and mail the coupon now for a supply of ARMCO blue and gold labels.

**The American Rolling Mill Co.**
**Middletown, Ohio**

Send me.....blue and gold labels.
Name.....
Company.....
Street.....
City.....State.....
We manufacture.....from ARMCO Ingot Iron

(The J. of A. C. Society—6-1-25)

## BUYERS' GUIDE (continued)

### J

**Jiggers**
Hadfield-Penfield Steel Co.
Mueller Machine Co., Inc.

### K

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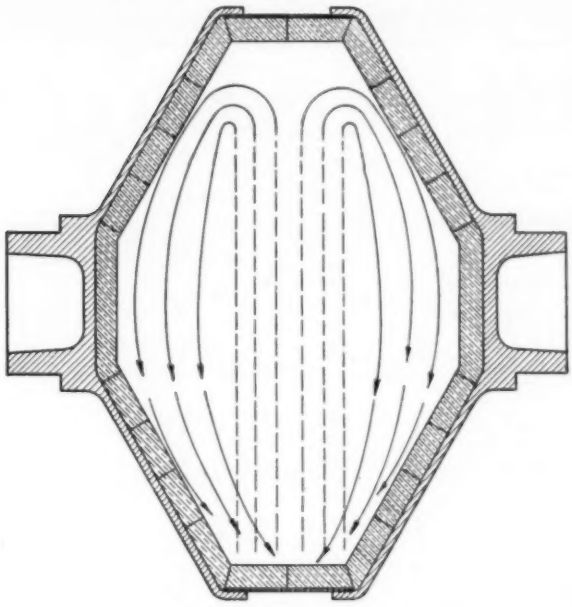

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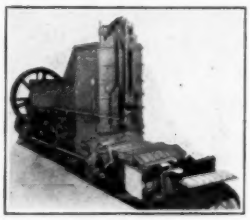

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Percentage of "Grit" and other impurities in clays after washing.

| Georgia Clay No. | on 325 mesh screen |
|---|---|
| G- 1 | 0.14 |
| G- 2 | 0.30 |
| G- 4 | 0.30 |
| G- 6 | 0.08 |
| G- 7 | 0.02 |
| G- 8 | 0.04 |
| G- 9 | 0.04 |
| G-15 | 0.04 |
| G-16 | 0.43 |
| G-24 | 0.02 |
| G-27 | 0.40 |
| G-28 | 0.20 |
| G-29 | 0.10 |
| G-30 | 0.13 |
| G-31 | 0.07 |
| G-32 | 0.03 |
| G-33 | 0.06 |
| G-34 | 0.08 |
| G-35 | 0.03 |
| G-36 | 0.04 |
| G-37 | 0.50 |
| G-38 | 0.17 |
| G-39 | 0.35 |
| G-40 | 0.04 |
| G-41 | 0.03 |
| G-42 | 0.07 |
| G-43 | 0.30 |
| G-44 | 0.13 |
| ¶ Paper Clay A | 0.17 |
| + Paper Clay B | 0.29 |
| = Paper Clay C | 0.80 |
| ‖ Paper Clay D | 0.27 |

¶ Georgia.
+ English.
= High Grade English.
‖ "Extra Grade" English.

These are only a few of the many highly illuminating facts established as a result of extensive experimentation by the Central of Georgia Railway cooperating with the U. S. Bureau of Mines to determine the commercial values of the vast deposits located in the Coastal Plain of Georgia and Alabama.

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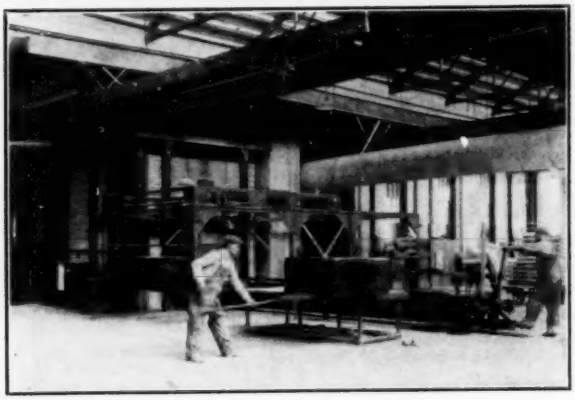

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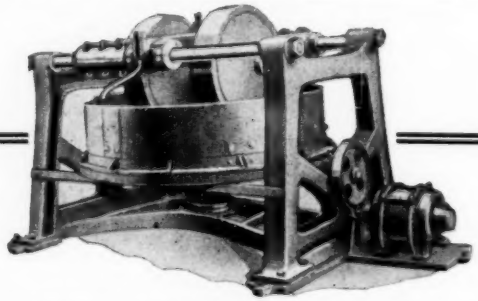

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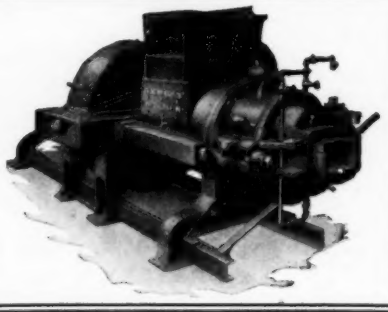

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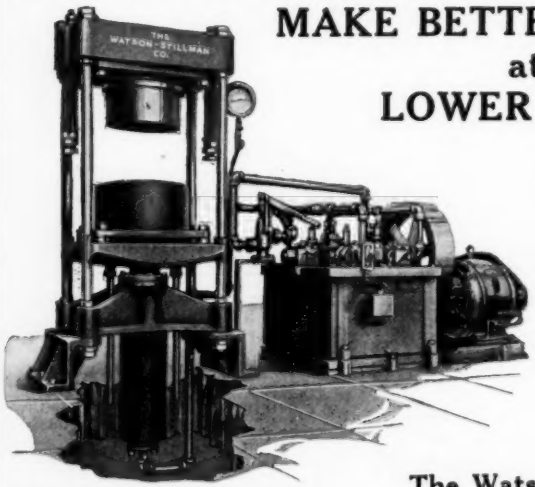


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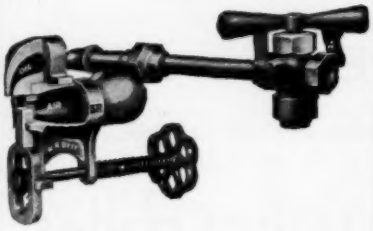

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# THE CERAMIC INDUSTRY'S BEST ASSET

BUILT RIGHT
RUN RIGHT
FOR CLAY WORKERS

The best Asset of the Ceramic Industry is quality of product and quality of product is largely dependent on properly prepared Materials. The American Wet Grinding Pan does its work thoroughly, quickly and cheaply. This is an unusually well built, dependable unit. Long on service. Light on power. Ask for Bulletin.

We build a complete line of machinery for Ceramic needs.

**The Hadfield-Penfield Steel Co.**
BUCYRUS, OHIO

# ENGELHARD PYROMETERS
*for*
# —TUNNEL KILNS—

Engelhard Pyrometers have many exclusive features that make them desirable for tunnel kilns, and they have been applied to almost every type of tunnel kiln.

A notable installation is on the Dressler Kiln at the Ford Motor Co's glass plant at Glassmere, Pa., which is used for pot heating for plate glass manufacture.

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that will actually help you develop profits is available.
"Nothing to Sell but Engineering Service
**C. FORREST TEFFT**
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**THE SHARP-SCHURTZ COMPANY**
Chemists for the Ceramic Industry
We have fully equipped laboratories at
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Consulting Ceramic Engineer
1625 Hobart St., N. W., Washington, D. C.
Competent men for responsible positions in the clay industries, available.


## CERAMIC BREVITIES

The Chicago office of Innis, Speiden & Co., Inc., Manufacturers, Importers and Distributors of Industrial Chemicals, heretofore located at 120 W. Kinzie St. has recently been moved to their new Chicago building at 722-724 W. Austin Ave., just completed as a combined office and warehouse. Their facilities for handling business in the Middle West are greatly improved,

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Mr. Fred W. Runge, formerly in charge of the enameling department of the Josiah Anstice Co., Rochester, N. Y., is now connected with The Ferro Enameling Co., Cleveland.

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The Cribben & Sexton Stove Co., Chicago, are installing a complete Bonnet Overhead Charging Fork and Double Unloader on one of their enameling furnaces. Installation is being made by The Ferro Enamel Supply Co., Cleveland.

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At the annual meeeting of the directors of the Wolverine Porcelain Enameling Co., Detroit, Mich., the following officers were elected: Heinrich Turk, President; Karl Turk, Vice-President; Emmet Dwyer, Vice-President; Alfred B. Moran, Secretary Treasurer; Joseph Hoehl, Assistant Secretary-Treasurer. Messrs. Heinrich and Karl Turk are President and Vice-President respectively of The Porcelain Enamel & Mfg. Co. of Baltimore; Mr. Emmet Dwyer is Vice-President and Factory Manager of the Michigan Stove Co., of Detroit, Mich.; Mr. Alfred B. Moran is Secretary of the Peninsular Stove Co., of Detroit, Mich.; and Mr. Joseph Hoehl is Superintendent of the Wolverine Porcelain Enameling Co.

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At the annual meeting of the directors of the Scranton Enameling Company, Scranton, Penna., the following officers were elected: Messrs. Heinrich and Karl Turk, President and Vice President respectively of the Porcelain Enamel & Mfg. Co., of Baltimore, were elected President and Vice-President respectively of the Scranton Enameling Co.; Mr. Thyge Smith of the Scranton Stove Company, Scranton, Penna., was elected Secretary-Treasurer of the Scranton Enameling Company.

# What's under the enamel determines several things

The appearance of the finished piece is of vital importance, and depends largely on the enameling base, yet the enameler depends for his profit on the percentage of perfect pieces he gets, and the reduction of culls to a minimum.

Here is where Toncan demonstrates its superiority as an enameling metal.

It doesn't warp in the fusing operation. It doesn't sag between burning points. It doesn't blister in the enameling process.

The result is a higher percentage of perfect pieces and a correspondingly higher profit.

The care and skill applied in every process gives Toncan Enameling Sheets a quality and uniformity seldom encountered in these days of quantity production.

If you are not using Toncan, it will pay you well to try it.

TONCAN METAL

**UNITED ALLOY STEEL CORPORATION**
**CANTON, OHIO**

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## TONCAN ENAMELING SHEETS

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**Zirconium Oxide Product**

The Ultimate Opacifier for Vitreous Enamels and Glazes.

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A refined Zirconium Silicate for Refractory Work and ground coat enamels.

**Electrically Fused**

(Lumps or Milled) 95% Zirconium Oxide. A super-refractory material for exceptionally high temperature work.

**(Granular or Milled)**

94% Titanium Oxide. A specially prepared product for Terra Cotta, Faience, Acid Resisting Enamels, etc.

## The Titanium Alloy Manufacturing Co.

**Ceramic Materials Department**

*R. D. Landrum, General Manager*

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Producers and Pulverizers of

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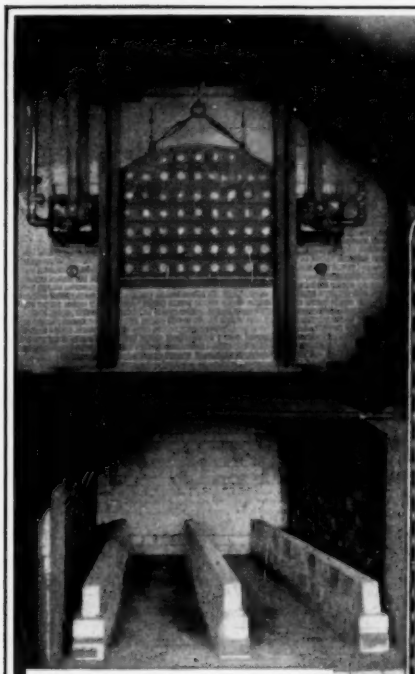

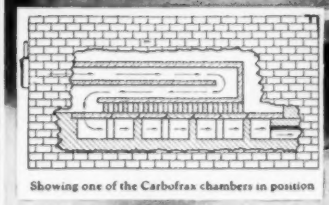

Showing one of the Carbofrax chambers in position

# Not In Years

*It's been a long time since a new enameling furnace created such an interest as has*

## The Carbo-Radiant

***The furnace that heats by radiation***

HERE is a furnace that heats by radiation but without a muffle—a simple, efficient, economical furnace that will lower enameling costs, produce better burned ware and increase production.

The furnace is heated from two combustion chambers made from Carbofrax—the Carborundum Refractory. These are placed at each side of the burning chamber and the exhaust gases pass to the stack under the hearth.

Within these chambers all combustion of gas or oil fuels takes place and the combustion is complete. There is no waste of fuel energy. There is no impingement of burning gases against any of the furnace brickwork.

With astonishing speed the heat radiates from these combustion chambers flowing through the Carbofrax walls so effectively that there is but ten degrees difference between the inside and the outside of these chambers. The reason is that there is no other refractory material that has the high heat conductivity of Carbofrax.

In the Carbo-Radiant Furnace there are no harmful gases or dirt—you are assured of uniformly burned, unspotted ware.

The furnace is compact and provides for practically a permanent installation, repair costs are negligible, no brickwork to keep up, no muffle.

It will increase plant production because almost the entire furnace area right up to the door jamb can be used. The uniformity of heat throughout the hearth makes this possible.

***Our Sales Engineering Department will gladly give further details***

**The Carbo-Radiant Furnace is designed, built, installed and guaranteed by**

**The Carborundum Company**
**Perth Amboy, N. J., U. S. A.**

## Carborundum
### Refractories

**Brick • Tile • Muffles • Cements**
**Hearths • Retorts**

This is your last chance to have your advertisement appear in THE CERAMIC DIRECTORY as we hope to have it on the presses by June 15th. Write, telegraph or 'phone if you want us to reserve you a space.

As far as we know, it is the only CERAMIC DIRECTORY covering raw materials, chemicals and colors, supplies and equipment bearing directly on the ceramic industry. It will be wise to take action immediately upon receipt of this Journal.

Advertising Department

American Ceramic Society

Lord Hall, O.S.U. Columbus, Ohio.

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Are known throughout the country for their *Quality* and *Uniformity*. They are especially suited for fine Ceramic Work.

Let us tell you of the many customers who have been using our clays close to 32 years. Write us.

EDGAR BROTHERS CO.

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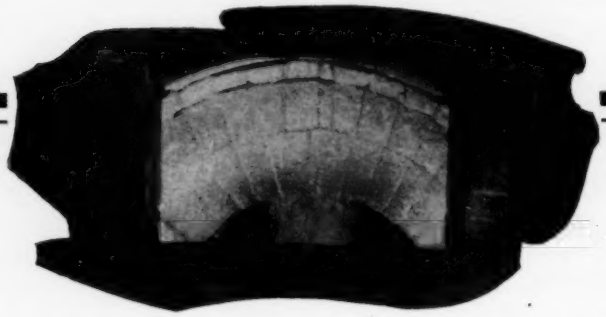

# Kiln Fire Box Bricks

Alundum and Crystolon Bricks are built for extreme temperatures. They give long and lasting service in kiln fire boxes.

These bricks are:

**Dense**
**True to shape**
**Physically strong**
**Very heat resistant**

Their use means fewer shut downs for repairs.

The difference in first cost is saved by using a high quality product.

All important shapes of the standard 9″ series are stocked for prompt shipment.

High grade bricks should be laid with a cement as high in quality. Alundum Cement fills the requirements to the highest degree.

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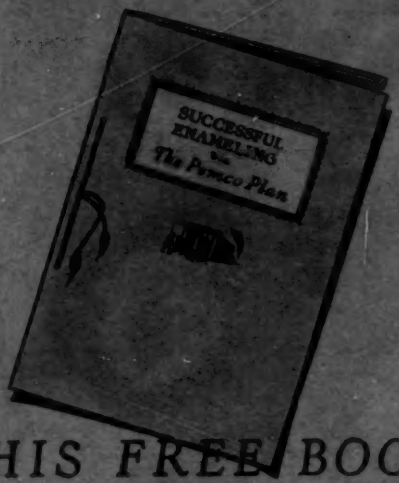


# THIS FREE BOOK

## *Gives Authoritative Data on the Enameling Industry*

This fifty-page royal octavo volume contains figures and plans; gives an outline history of the industry; probable future development; territorial markets; new markets; new uses; new products; applying processes; applying costs, in detail, item by item; itemized lists of equipment for complete plant, priced by item; outlines the Pemco Plan.

One firm wrote: "Without doubt, the most complete and comprehensive description of a line that has ever come into our office." The first edition was exhausted in eleven days. The second edition is now ready. Sent free without obligation, write today for your copy.

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